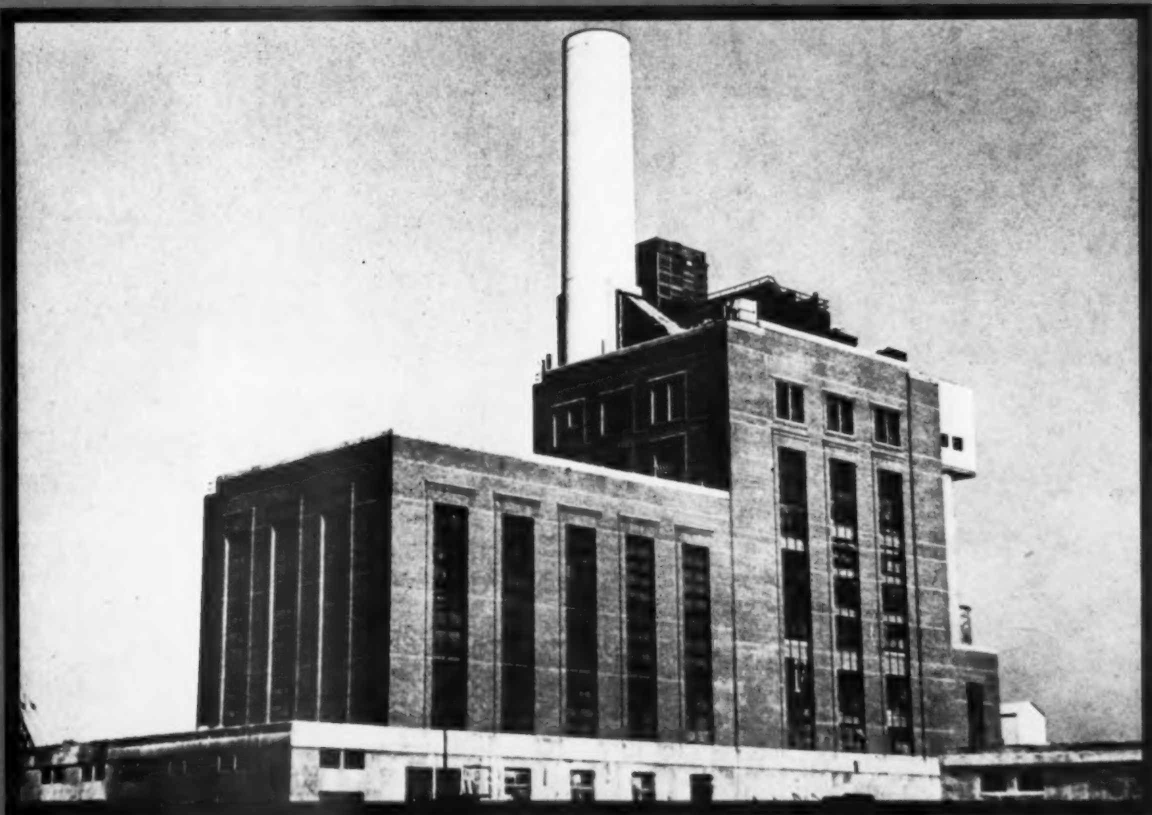
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

December, 1943



New Mystic Power Plant of Boston Edison Company

Steam Power and Fuel Problems Predominant at A.S.M.E. Annual Meeting ▸

Addition to Capacity and Modernization of the MARYSVILLE POWER HOUSE ▸

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME FIFTEEN NUMBER SIX

CONTENTS

FOR DECEMBER 1943

FEATURE ARTICLES

EDITORIALS

DEPARTMENTS

H. STUART ACHESON, *Advertising Manager*

ALFRED D. BLAKE, *Editor*

THOMAS E. HANLEY, *Circulation Manager*

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EDITORIAL

The Gas Turbine

Considerable general publicity has lately been accorded the gas turbine, and to some this appears to presage a revolutionary change in power generation.

The idea of the gas turbine is not new; many such patents were issued during the last century, and it has been the subject of much research in both this country and abroad over the last forty years. In such work Dr. Sanford Moss, often referred to as the father of the airplane supercharger, has played an important rôle.

At present, several installations are operating in the United States, driving compressors in connection with certain oil-refining processes; but not commercially as prime movers driving electric generators. Abroad, one such installation has been made in a 4000-kw standby plant at Neuchatel and a gas-turbine locomotive has been built for the Swiss Federal Railways. Moreover, several well-known firms in the United States are now engaged in gas-turbine development.

A recent issue of *Brown Boveri Review*, which speaks authoritatively for the firm contributing most to gas turbine development abroad, considers this type of prime mover to be applicable to driving blowers for steel mills, for peak load and standby plants and for certain other special applications, within a range up to 10,000 kw, and where the fuel is gas or oil and efficiency not paramount.

While there does not seem to be any immediate prospect of the gas turbine becoming a serious competitor of other forms of power generation, the standing of those engaged in its development and the availability of materials to withstand high temperatures warrant maintenance of an open mind on the subject.

A Constructive Research Project

During periods of much construction activity, projected improvements and innovations in design are likely to be introduced so fast that there is little time to try out and segregate their relative values. Hence, the last two or three years of enforced lull in electric utility construction have afforded an opportunity to assess certain of the advances made during the period immediately preceding.

The several sessions on Furnace Performance Factors at the A.S.M.E. Annual Meeting, in which operating experiences and current investigations were frankly discussed by engineers of both the utilities and the equipment manufacturers, should lead to a better understanding of many of the factors involved. The knowledge gained will undoubtedly be reflected in post-war design. A number of the papers and some of the discussion revealed the extent to which systematic studies have been undertaken with regard to certain problems, to the end that more precise design factors, within the limits of fuel variability, may be available.

The work of the Special Research Committee on Furnace Performance Factors appears to have got off to a good start. Its agendum has been well conceived; its financial support is promising; and it has enlisted the active cooperation of those in a position to render constructive assistance. Its further contributions, over a long-range program, give promise of very substantial return on the effort and expense involved.

Significant Facts on Oil Demand

The fact that the Government saw fit a few months ago to rescind its orders on conversion from oil to coal, must not be regarded as an assurance of oil availability over any considerable period. Instead, it appears to have been an expedient to cope with a critical coal situation arising from lost production due to strikes.

Following are some pertinent facts brought out at the recent Annual Meeting of the American Petroleum Institute, in Chicago, which indicate what prosecution of the war during the coming year will mean in terms of increased oil demands:

The military program for 1944 includes more than twice as many heavy trucks as will have been turned out in 1943.

The current output of high-octane gasoline will be doubled within a few months.

The Navy's consumption of fuel oil this year has been more than double that of last, and will be increased still further in 1944 as new ships are commissioned.

It takes nearly three tons of gasoline to deliver one ton of bombs on an enemy objective, and to date we have produced more than 1,600,000 tons of aerial bombs.

In October 1943 we turned out three times as many four-engined bombers as were produced last January and the limit has not yet been reached.

Aside from oil used by the Navy and by supply ships, or that supplied to our allies, every American soldier overseas requires an average of more than fifty gallons of petroleum products per week.

Meanwhile, more and more merchant ships are being put into service and the stepped-up tempo of the Pacific warfare means increased shipping over vast distances.

The Number One problem of the oil industry is to find new reserves and, according to Deputy Petroleum Administrator Ralph K. Davies, current studies show that it is four or five times as difficult and costly to find a barrel of new reserves today as it was in the pre-1938 period.

These are but a few of the factors bearing on increased demands, but they should serve to discount any feeling of security on the part of oil consumers that may have been engendered by the Government's action regarding conversions.

It is undeniable that we still have a more or less dislocated coal situation, particularly in certain localities, but this should improve as the months go by; whereas the effects of an overtaxed oil supply are likely to endure.

Steam Power and Fuel Problems Pre- d

WITH sixty-eight technical sessions and panel discussions comprising more than two hundred prepared papers, the Sixty-Fourth Annual Meeting of the American Society of Mechanical Engineers, held at the Hotel Pennsylvania, New York, November 29 through December 4, marked a new record for such meetings of the Society, particularly in the scope of subjects discussed. In the following report only those subjects of particular concern to steam power engineers are reported.

Furnace Performance Factors

A high spot of the technical program was a series of three sessions, sponsored by the Power Division and arranged by the A.S.M.E. Special Research Committee on Furnace Performance Factors.

The first of these sessions centered around the performance and experiences with the high-pressure installation at the Twin Branch Station of the Indiana & Michigan Electric Company and consisted of three papers, namely (1) "Operating History of the 2500-psi Twin Branch Plant," by Philip Sporn and E. G. Bailey; (2) "Natural Circulation Test Results in the 2500-psi Twin Branch Boiler," by W. H. Rowand and T. B. Allardice; and (3) "Distribution of Heat Adsorption and Factors affecting the Performance of the Twin Branch 2500-psi, 940-F Boiler with Reheat to 900 F," by E. G. Ely and L. B. Schueler.

The paper, by Messrs. Sporn and Bailey, reviewed the experiences from the time the unit was placed in operation in March 1941 to August 31, 1943, and detailed the various alterations that were made during this period involving redistribution of heat-absorbing surfaces to correct superheat and reheat temperatures and certain furnace alterations to cope with the Indiana coal being burned. Orifices were also inserted in the downcomers to stabilize water level. Since April 1943 the unit has been operating at the design values.

When it was proposed to install a 2500-psi natural circulation boiler of 550,000 lb per hr capacity at Twin Branch the question of natural circulation for such a high pressure was thoroughly considered, especially since the density differential between water and steam at 2400 psi is only 28.4 as compared with 39.8 at 1400 psi. This phase of the problem was discussed in the paper by Messrs. Rowand and Allardice which described tests on a full-diameter, half-length model of the drum and downcomer pipe at Ohio State University, also circulation measurements on the actual unit after installation.

Briefly, the design incorporates outside downcomers feeding the lower drum, with direct supply lines to all generating circuits and cyclone separators in the steam drum. By the insertion of $16^1/_4$-in. orifices in each of the 28-in. diameter end downcomers the circulation ratio was reduced to approximately 10 and drum water level instability was thereby corrected. The velocities after installing the orifices range from 2 to 4.5 fps entering the tubes at maximum load. Since the tubes of the upper furnace walls were changed to full stud construction and sinuous tubes placed in front of the reheater in the open pass, thermocouple measurements at full load indicate local absorption rates ranging from 30,000 to 55,000 Btu per sq ft per hr.

The conclusion reached by the authors was that natural circulation in boilers operating at around 2500 psi is entirely feasible.

The third paper, by Messrs. Ely and Schueler, brought out that for the design conditions obtaining at Twin Branch nearly one-half the heat absorbed is by steam-cooled surfaces and that the ultimate margins of temperature between the steam and the safe metal limits are largely consumed by steam-film and tube-wall gradients. Initial operation had indicated that the heat absorbed by steam, particularly in the reheater, was too great, and that the full temperatures of superheat and reheat were obtained at approximately 70 per cent load, using all the gas-bypass and attemperator-control capacity available. This condition initiated a comprehensive field investigation and heat absorption tests, the results of which were reported in the paper, and led to a re-apportioning of heating surfaces.

It was further established that slag peeling in certain portions of the primary furnace, particularly where both radiation and convection heat exchange were imposed on the tubes, could result in absorption rates as high as 200,000 Btu per sq ft per hr. Samples of slag collected daily from the tap stream have shown appreciable variations in fusing characteristics and in the state of oxidation of the iron content, and other samples collected from different parts of the unit showed diversities of composition and fusing-temperature range. Also, it was apparent that the effect of iron, which in its ferrous form acts as a dominant fluxing agent, is materially altered both by segregation of quantity and state of oxidation in passage through the unit.

The authors stated that the final alterations that had permitted continuous base-load operation, consisted principally of reducing the amount of exposed surface in certain of the superheater and reheater sections and the provision of retractable blowers in the second open pass. Their conclusions observed that boiler design in the high-temperature portion of a unit of the type under discussion is still far from being a precise and formulated science in view of difficulties in measurement of high gas temperatures and quantitative determination of the insulating effects of ash and slag; furthermore, that the range of day-to-day variations in operating conditions must be adequately explored and appreciated in order to provide satisfactory margins of control.

The unit, as at present, over a period of 3800 hr has shown an availability of 96.7 per cent and the high-pressure plant extension a station heat rate of 10,035 Btu per kw-hr.

Discussion

In discussing this group of papers, W. H. Armacost, after complimenting the authors on the frank and full presentation of the operating history of this unit, offered some additional information on operation of the 2000-lb,

dominant at A.S.M.E. Annual Meeting

960-F controlled forced-circulation unit at Montaup which was described in a paper at last year's Annual Meeting. This unit, it will be recalled, has small tubes of $1^1/_4$ in. diameter and extensive temperature measurements under normal operation have shown a maximum metal temperature of only 130 deg F above saturation temperature of the steam with a circulation ratio at Montaup of 5 to 1. There had been two tube failures since starting up in August 1942, due to oxide scale from fired welding and this led to acid washing of the unit. No mechanical changes have been found necessary since the boiler was erected and, except for alterations in drum internals, none is contemplated.

I. E. Moultrop reviewed the advances in steam conditions since the first 1200-lb boiler was installed at Edgar Station twenty years ago. He credited much of the progress in steam-generating practice and economy to the cooperation between manufacturers and users of power-plant equipment, and to their willingness to make their experiences known to the engineering fraternity.

J. C. Hobbs described the 300,000-lb per hr, 2200-lb pressure unit that has been in successful operation for the last five or six years at the Painsville, O. plant of his company. This unit, of simple design, absorbs practically all the heat by radiation (excepting that absorbed by the superheater, economizer and air heater), and operates with very low furnace temperatures. The circulation ratio in this case is 17 lb of water per pound of steam.

The second session on "Furnace Performance Factors" included papers on "Furnace Design and Development of Steam-Generating Units Burning Central Illinois Coal," by J. R. Michel; "Collection of Data on Existing Installations," by Philip Sporn; and "Pulverized-Coal-Fired Boiler Furnaces," by Herman Weisberg; "Performance of Boilers 12 and 14 at the Trenton Channel Plant and Boilers 9 and 10 at the Marysville Plant of The Detroit Edison Company," R. J. Brandon and W. A. Carter; "Statistical Information on Large Pulverized-Coal Units on the Consolidated Edison System," by W. E. Caldwell; and "Performance of Pulverized-Coal-Fired Boilers on the Philadelphia Electric Company System," by J. H. Harlow.

Experiences at Chicago Stations

Mr. Michel reviewed the experiences in burning Central Illinois coal at three Chicago generating stations of the Commonwealth Edison Company. This coal, while having certain characteristics adapting it to burning in pulverized form, also possesses disadvantages. It is free-burning, high in volatile, has low ash-fusion temperature, high ash content, runs high in sulphur and has low grindability. The high-ash content and low ash-fusion temperature, while permitting ready tapping in wet-bottom furnaces, tends toward severe slagging of the heat-absorbing surfaces.

At the Crawford Avenue Station, where this coal has long been burned on stokers, and notwithstanding the installation of mechanical blowing equipment, it was formerly necessary to remove boilers from service at 35-day intervals for hand rodding and repairs. However, through the employment of washed coal, these boiler service periods have been increased to 75 or 80 days without hand cleaning or water lancing while the units are in service. The extra cost of washed coal in this instance was economically justified in view of the radical changes that would have been necessary to overcome slag fouling difficulties.

In 1937 a topping unit was installed in a second Chicago station and this was supplied with steam by two 375,000-lb per hr 1275-psi, 910-F pulverized-fuel-fired boilers. Unwashed Central Illinois coal was burned because of economic considerations. In this installation slag screens were provided between the primary and secondary furnaces, wide tube spacings were employed in the steam-generating banks of the tubes, telescoping deslagging units were installed in the steam-generating banks and superheaters, and provision was made for hand lancing in addition to the usual complement of mechanical blowers. Despite these measures, a constant cleaning program was found necessary in order to maintain the boilers in proper operating condition and the full time of three boiler cleaners on each watch is required. With this arrangement six months' operation of the boilers is obtained before outage for regular inspection, maintenance and cleaning is necessary.

In view of the foregoing experience when three 425,000-lb per hr, 1325-psi, 935-F steam-generating units of a different type were later required for a third station of the company, the design stipulations covered lower unit furnace heat release, wide spacing of the steam-generating tubes and consequent lower entering gas velocity to the tube banks, wide spacing of superheater tubes with entering gas temperatures of approximately 1900 F, and provision for hand-lancing doors so disposed as to permit cleaning of all heat-absorbing surfaces while the boilers were in service. Also, to overcome the difficulties experienced with telescoping deslagging units, as used in the previous installation, mass blowers were employed where possible and rotating retractable elements installed above the steam-generating tube bank and in the superheater.

Operation of these boilers since January 1942 has indicated that the steps taken to eliminate difficulties due to slag fouling of heat-absorbing surfaces were ample, since operation of the mechanical blowers twice daily maintains the boiler units in clean operating condition.

On the basis of this performance, when 750,000-lb per hr high-pressure steam-generating units were being considered for installation in a third station the same stipulations as to lower heat release, tube spacing, low-gas velocity and provision for blowing were made and indications are that no hand lancing will be necessary.

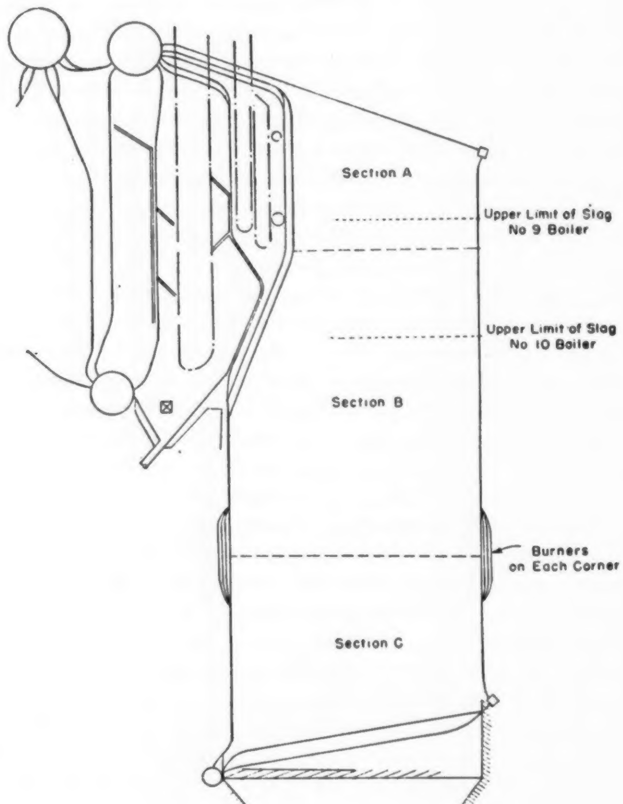
Boilers on Public Service System

The paper by Mr. Weisberg presented statistical information on pulverized-fuel furnaces as installed in various plants of the Public Service Electric and Gas Company of New Jersey. Reasons for the selection of the various designs employed were given and their oper-

ating conditions discussed. The author's conclusions were that more information is needed on burners, arrangement of water-cooled furnace walls for maximum heat absorption, methods for predicting and controling slag deposits on furnace walls, measures to eliminate destructive action of furnace atmosphere and slag on water-cooled metal-wall surfaces, and arrangement and spacing of tubes in the convection bank for slag-free operation with various furnace-exit gas conditions.

Detroit Units Compared

Boiler No. 12 at Trenton Channel is of the double-set Stirling type with five drums and pulverized-coal fired from a storage system. It was installed in 1927 and rated at 250,000 lb of steam per hour at 400 psi and 700 F. Boiler No. 14, installed in 1929, is similarly fired, has the same rated capacity and steam conditions and is of the double-set C-E bent-tube type. The coal for which the units were designed analyzed 32.6 per cent volatile, 5.58 per cent ash, 13,173 Btu per lb and had an ash-softening temperature of 2640 F. The designed furnace heat release for both boilers was 13,140 Btu per cu ft per hr.



Sketch indicating slag distribution

No serious trouble has ever been encountered because of slagging on any of the tube surfaces of these boilers when burning coals having ash-softening temperatures of 2500 F or higher, although some plugging of gas passages in the front convection banks has occurred at high steaming rates when burning coals having ash-softening temperatures of 2300 F or lower; but such deposits are readily removed by steam lancing once every eight hours. However, at times, ash in the form of dust collects on the hearth-screen tubes, thereby reducing their heat absorption and increasing the furnace temperature to such a point as to cause slag reaction with the air-cooled refractories in the furnace walls. Slagging of these walls usually occurs before any deposits start to collect on the tubes.

Boilers Nos. 9 and 10 at Marysville were installed in 1942 and are of the C-E three-drum bent-tube type with completely water-cooled walls, and tangentially fired dry-bottom furnaces. They were designed for a steam output of 350,000 lb per hr at 865 psi and 910 F with 12,924-Btu coal having 33.57 per cent volatile and 8.23 per cent ash which has a softening point of approximately 2700 F. The calculated furnace heat release is 15,660 Btu per sq ft per hr.

Slagging of the water-wall surfaces has not been serious since the light ash deposits can be removed readily by air lancing. It has been found that slag tends to accumulate more quickly when the flame is sluggish or impinges on the walls, but this condition can be improved if the secondary air is regulated to obtain optimum air velocity and distribution over the range of steaming rates. A change in steaming rate will bring about some deslagging.

In order to indicate the distribution of slag on the water-wall tube surfaces, the furnace has been divided sectionally as shown in the accompanying sketch. Very little slag collects on the water-walls in sections *A* and *C*, but the tubes in section *B* become heavily covered with nodulized deposits which are removed regularly for steam temperature control. The entire area in section *B* becomes covered, and the deposited ash is removed by air lancing when approaching two inches in thickness. All four walls receive about the same amount of slag, with the heaviest deposits forming above and on one side of the burners and decreasing in amount higher up in the furnace. In No. 9 boiler, the slag in section *B* collects more quickly and extends to a greater height than in No. 10 boiler, which is a duplicate.

Units in Three Philadelphia Stations

J. H. Harlow reported on the furnace performance of three different types of pulverized-coal-fired boilers installed, respectively, in the Richmond, Schuylkill and Chester Stations of the Philadelphia Electric Company All are rated at 600,000 lb of steam per hour and the respective operating conditions are 425 psi, 850 F; 1350 psi, 910 F; and 1350 psi, 925 F, with two such units in each of the stations. Slack central Pennsylvania coal is burned, ranging from 14,120 to 14,400 Btu per lb, dry; and 7.1 to 9 per cent ash with ash-fusing temperature from 2450 to 2600 F. The grindability varies from 115 to 125 on the Hardgrove index.

The boilers at Richmond and Chester are of the straight-tube single-drum type with primary furnaces having intertube down-fired burners; while those at Schuylkill are of the three-drum bent-tube type, the furnaces being fired tangentially by three burners in each corner. All the furnaces have slagging bottoms. In each case the minimum load for satisfactory tapping appears to be at about two-thirds of rated capacity.

At Richmond Station retractable wall blowers using steam have been installed to remove slag on the furnace

screen, and telescopic water lances are employed for the lower bank of generating tubes. Regular operation of these devices together with about 160 man-hours per week per boiler of hand lancing serves to keep the boilers in condition.

At Schuylkill Station, in addition to taking advantage of the daily drop in load, slag is removed from the furnace walls by hand lancing with air and water, about 20 man-hours per week per boiler being required. An additional 60 man-hours per boiler per week are required to remove accumulations not reached by the soot blowers, such as the front bank of generating tubes and the superheater.

At Chester no trouble has been experienced in the removal of primary furnace slag, nor that in the generating tubes or superheater. Most of the slag which must be removed accumulates in the upper part of the second open pass and this is removed by hand lancing which requires about 55 man-hours per boiler per week.

Furnace-wall tube wastage has been encountered in all three installations, that at Schuylkill having been more accelerated. This has been attributed to a combination of reducing atmosphere and burner design, and although corrective measures have been taken in each case, the true mechanism of the wastage is the subject of an investigation now being carried on elsewhere.

At the third session on "Furnace Performance Factors," papers were presented by Henry Kreisinger and R. C. Patterson on "Heat Transfer to Water-Cooled Furnace Walls"; by John Blizard on "Absorption of Heat by the Walls of a Furnace"; and by W. T. Reid and P. Cohen on "The Flow Characteristics of Coal-Ash Slags in the Solidification Range.

Heat Transfer Measurements

The first of these papers reported the results of measurements of the heat transfer to water-cooled furnace walls of two pulverized-coal-fired boilers, one having a slagging-bottom furnace of the intermittent tapping type and the other a furnace of the dry-bottom type. Both were tangentially fired, the former having two burners per corner and the latter, three. The slagging-bottom furnace had plain tube walls and the dry-bottom furnace fin-tube walls. Heat transfer was measured with small heat-absorbing units placed at different elevations in one of the walls of the furnace, and each unit was supplied separately by water which was weighed and its rise in temperature noted in order to determine the heat absorbed. These units remained in the furnaces for several weeks so that the condition of their external surfaces was substantially the same as that of the walls.

The ash deposit on the walls of the two furnaces differed. That in the slagging-bottom furnace with plain-tube walls was in the form of a thin sheet of semi-fluid slag extending from the bottom of the furnace to a height of 10 or 12 ft, above which the deposit gradually became thicker and assumed a spongy crust near the top of the furnace. That on the walls of the dry-bottom furnace varied from a thick layer of porous slag in the burner belt, through crusted ash at the elevation of the lower drum, to a dusty film at the top of the furnace. Below the burner belt the deposit consisted mostly of crusted ash and dust.

The heat transfer varies directly with the steam output of the boiler and inversely as the thickness of the ash deposit on the test units. Transfer to the test units was somewhat higher than that to the walls because the temperature of the test units was lower, but the difference was small. Heat transmitted by radiation is proportional to the difference between the fourth powers of the absolute temperatures, whereas that transmitted by conduction is proportional to the difference between the temperature of the surface of the ash deposit and that of the tube metal, and inversely proportional to the thickness of the ash deposit.

Charts were presented showing the heat transfer as varying with steam flow, for the top, middle and bottom units for both furnaces. These values ranged from around 20,000 Btu per sq ft of projected surface per hour to 140,000 Btu for the slagging-bottom furnace, and from around 20,000 Btu per sq ft of projected area per hour to 100,000 Btu for the dry-bottom furnace. Units inserted nearer the bottom of the furnace showed the higher heat absorption. Moreover, it was pointed out that some of the surface transmitted several times the amount of heat as did other surfaces, so that calculation of the average heat transfer for the entire furnace would be difficult. Indications were, however, that about 95 per cent of the heat was liberated within the first 10-ft height of the slagging bottom furnace.

Measurements on Oil-Fired Unit

Mr. Blizard in the second paper at this session reported on measurements made on a 525-psi, 700-F oil-fired boiler having two furnaces, one of whose sides was formed by superheating tubes and the other, boiler tubes. That is, the gases of combustion from the first furnace first passed over two rows of superheater tubes and four rows of boiler tubes before entering the main furnace, thence over the main bank of boiler tubes to the economizer and uptake. The walls of the unit were of brick and the heat transmitted to the walls was mainly by radiation.

During the tests the total supply of oil and water to the boiler was weighed and the distribution of oil between the two furnaces was estimated from the relative values of the pressure of the oil at the two sets of burners, as well as the number of burners in use in each furnace. The enthalpy of the steam entering the superheater was measured by a throttling calorimeter and its enthalpy leaving was determined by measuring its temperature and pressure. Composition of the gas leaving the economizer was measured at eight points.

The rate of heat absorption by convection was estimated from the rate of flow of gases over the two rows of superheater tubes and from the gas temperature leaving the superheater. This ranged from 4600 to 25,000 Btu absorbed per sq ft per hr, depending on the rate of firing. The heat absorbed by radiation, over the same range in load was from 9500 to 97,000 Btu per sq ft per hr. The radiation factor increased with the rate of firing.

Flow Characteristics of Coal-Ash Slags

Data on the flow properties of coal-ash slags below the temperature at which crystals separate from the melt on cooling, were presented in a paper by W. T. Reid and P. Cohen, both of the U. S. Bureau of Mines. The authors, after describing the instrument employed in mak-

ing the investigation, showed that these solids cause an abrupt change from liquid to plastic flow, the transition point being termed the "temperature of critical viscosity." Plastic viscosity is demonstrated by the development of an internal structure in the slag, which requires the application of a finite stress to produce initial deformation, and offers an explanation for the variable behavior of slags while freezing.

The temperature of critical viscosity is affected by a change in the composition and ferric percentage of a slag, although no simple relationship exists. It was stated that, for a given state of oxidation, this temperature decreases as the equivalent Fe_2O_3 content of the slag increases, the effect being most noticeable for small quantities of calcium oxide. Also, for a fixed equivalent Fe_2O_3 content, increasing calcium oxide decreases the temperature of critical viscosity. The greatest change, however, occurs with a change in the state of oxidation of the slag.

Comparison of cone-fusion data with equilibrium values of slag viscosity show that the latter is not a constant for any given state of deformation of cones, but an approximate relationship exists between cone-fluid temperature and absolute viscosity of slags from cone-fusion data.

The authors then discussed the effect of rheological properties (deformation and flow) on the thickness of slag on heat-absorbing surfaces, as in boiler furnaces. Because of the complicated physical process involved, certain assumptions were necessary in arriving at the following equation for estimating the thickness of slag desposits in relation to the temperature of critical viscosity, the viscosity as a function of temperature, the density, the rate of slag supply to the wall and the temperatures of the hot and cold faces of the slag deposit:

$$V = \frac{\rho d^3 \sin \alpha}{A^3 \Delta t^8} f\,(A, B, z, t\omega, \Delta, t, T_{cv})$$

where

V = volume of slag flow
ρ = density of slag (assumed constant)
d = thickness of slag deposit
A, B, and z = parameters in equation relating viscosity to temperature, $n^{-z} = A_t - B$
α = angle of inclination of wall to horizontal
$t\omega$ = temperature at cold side of slag deposit
Δt = temperature drop across slag deposit
T_{cv} = temperature of critical viscosity

Committee Summary

A. R. Mumford, Chairman of the Special Research Committee on Furnace Performance Factors, submitted a summary of reports of physical data on representative boiler units reported by eight operating companies. The capacities of these units range from 250,000 to 1,000,000 lb of steam per hour at pressures from 275 psi to 1600 psi and total steam temperatures from 700 to 960 F. It is the purpose of the Committee to analyze these data in an attempt to evaluate the importance of the geometry of a furnace as a factor in its performance.

A preliminary study indicates that the length of the path of the flame, before making contact with convection surface at the point of discharge from the furnace, varies from 108 ft in one unit to 33 ft in another.

In setting up a comparison of the various furnaces, the ratio of bounding surface area to the volume of a sphere was considered as unity. The surface of a sphere was computed for each furnace and the ratio of the actual surface to this minimum enclosing surface was computed as the spherical ratio. The larger this ratio, the less the cross-sectional area of the furnace and the greater its length in the direction of flame travel. For the units reported, this spherical ratio varied from 0.765 to 3.263. A value below unity is obviously impossible if the furnace is completely water-cooled and is possible only when exposed refractory is present.

For a few of the units, data were reported on the amounts of steam used for blowing ash from the heat-absorbing surfaces. When this amount of steam, computed on the basis of the quantity of fuel burned, was plotted against the liquid temperature of the ash, a fair degree of proportionality was found except in the case of one unit which was a mercury boiler. This, however, was not comparable because of the temperature of the heat-absorbing surfaces.

An interesting sidelight on design features was indicated when the Btu absorbed per square foot of free area at the entrance to the superheater was plotted against the Btu fired divided by the same divisor. Although the data covered quite a range of temperatures and pressures with consequent variation in the proportion of heat for superheating, the Btu fired was proportional to the Btu absorbed, with little scattering of the points.

A large proportion of those reporting, have apparently adopted the practice of sharply reducing or completely dropping load at regular intervals as a deslagging measure.

One company reported that steam temperature fluctuations on swinging load are minimized by using steam jets to clean evaporating wall surface on rising superheat and radiant superheater walls on falling superheat. Another stated that the service period of stoker-fired boilers was increased two to two and a half times and hand lancing during service hours eliminated by burning washed coal. Still another company reported that variation in ash-fusion temperature had not seriously affected slag tapping but that it had unbalanced the superheat characteristics, because low ash-fusion temperatures had caused the deposit on evaporative walls to become thinner and thus increase the furnace heat transmission

High-Temperature Steam Corrosion

Results of studies extending over a period of five years at The Detroit Edison Company to determine the rate of corrosion and the relative corrosion resistance in an unstressed condition of various power plant materials, were reported in a paper by Messrs. Rohrig, Van Duzer and Fellows of that company.

Specimens were exposed in a steam atmosphere at 380 psi and at temperatures of 925 F and 1100 F for periods ranging from 4000 to 16,000 hr. Some forty-six different materials were involved including nickel, nickel-copper alloys, chromium and chromium-nickel stainless steels, medium- and low-alloy steels, carbon steels and alloy cast iron. Weight-loss, hardness and metallographic data were obtained after successive exposure periods for many of the samples. The results indicated that:

1. In general, ferrous alloys containing high percentages of chromium alone are corrosion-resistant in steam at 1100 F.

2. Ferrous alloys containing high percentages of chromium and nickel are corrosion-resistant in steam at 1100 F.

3. Nonferrous alloys containing high percentages of nickel and copper that were tested in either 925-F or 1100-F steam can be expected to corrode in steam at those temperatures.

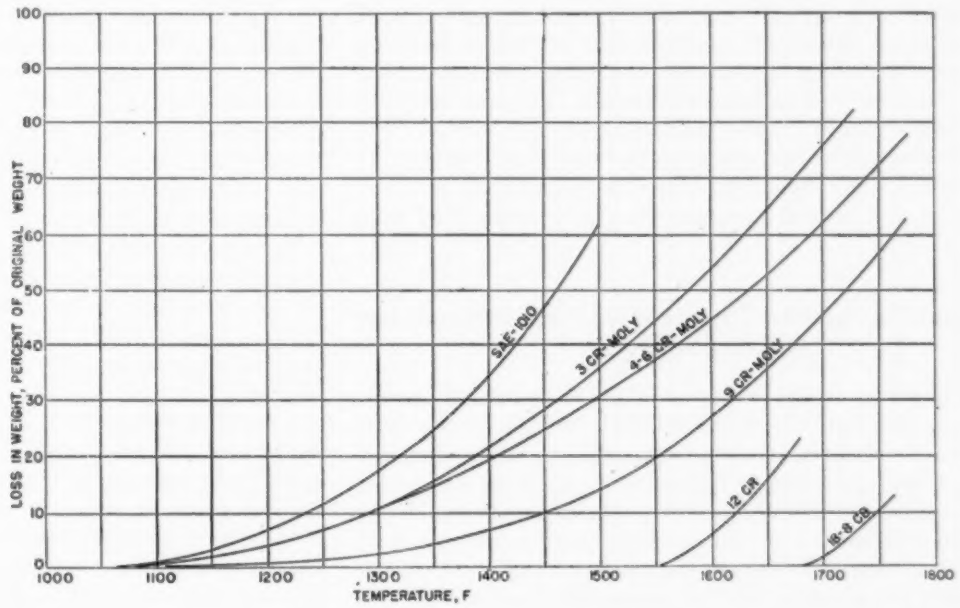
4. Although significant differences exist between the corrosion rates of carbon steels and medium- or low-alloy steels at 1100 F, at 925 F only a slight difference exists.

5. At both 925 F and 1100 F many steels that have a relatively low-alloy content compare favorably in corrosion resistance with steels of medium-alloy content.

6. The formation and maintenance of an adherent scale materially increases the corrosion resistance of samples exposed to high-temperature steam.

7. Trends in the reaction between steam at high temperatures and the various steels for which weight-loss rates were determined appear to have been demonstrated, and users can be assured that the rates of corrosion in steam atmospheres will not continue to increase. In fact, they flatten out or reduce as has been shown in the case of many low-alloy steels after 15,000 to 16,000 hr at 1100 F.

As for several years past, Messrs. Hawkins, Agnew and Solberg reported on further progress in the investigations that have been long under way at Purdue University on the Corrosion of Alloy Steels by High-Temperature Steam. The data presented this year dealt with the relative resistance to corrosion of unstressed specimens of various alloys at steam temperatures between 1000 F and 1800 F.



Curves showing the relative corrosion rates for several alloys

All of the steels tested, except for the very high chromium-nickel alloys, started to corrode rapidly at some temperature less than 1675 F, the limiting temperature being governed by the chromium content. However, after a break occurs the rise in corrosion rate is much more rapid for steel containing 12 per cent chromium and the 18–8 stainless steel than for those containing less chromium. The 25–20 and 25–15–2 W steels which were tested at temperatures of 1751 F showed no corrosion at the end of 500 hr. The 18–8 Cb steel shows the same tendency toward rapid corrosion above some limiting temperature that the S.A.E. 1010 steel shows at a much lower temperature. The curves herewith show the relative corrosion rates of several steels. Data were also presented relative to the chemical composition of the scale layers formed during tests at 1500 F and 1800 F.

Potassium Salts Replacing Sodium Salts in Boiler-Water Conditioning

"A New Approach to the Problem of Conditioning Water for Steam Generation" was the title of a paper by R. E. Hall in which the author described a method of treatment employing potassium salts to replace the sodium salts now in general use. Based on more than a years application at Springdale Station and subsequent use in other plants, indications are that the formation of troublesome sludge in the boiler can be reduced; that the formation of silica scale can be prevented; troublesome deposits on turbine blades greatly reduced or eliminated; and that damage to internal boiler-heating surfaces, as evidenced by the formation of magnetic iron oxide, can be reduced or prevented.

Potassium, while complementary to sodium, behaves differently in that certain of its compounds are more soluble at high temperatures than are the corresponding sodium salts. Also, it has been found that potassium salts are not as susceptible to "hide-out" within the usual range of boiler-water temperatures and concentrations, as are sodium sulphate, sodium phosphate and sodium silicate.

Furthermore, while silica is generally considered as undesirable in boiler water, the new method actually prescribes a small amount, as potassium silicate, for the purpose of reacting with magnesium to form a magnesium silicate sludge which is less objectionable than magnesium phosphate from the standpoint of adherence to heating surfaces.

The formation of magnetic iron oxide with attendant loss of metal from the heating surfaces has been ascribed to the momentary concentration of sodium hydroxide just before a steam bubble becomes detached from the metal. Concentration of salts in the film of the bubble

continues until the vapor pressure of the solution equals that of the vapor within the bubble, and by carrying the proper ratio of chloride to hydroxyl ion, the concentration of the latter is greatly reduced.

With reference to the reduction in silica deposits on turbine blades, it appears that at alkalinities generally carried in boilers the sodium silicate carried through the superheater is in a form that will precipitate silica more readily in certain stages of the turbine than will the corresponding potassium silicates and that the latter can be removed easily by washing with wet steam.

In condensing plants supplied with evaporated makeup water, the feedwater is practically devoid of sodium save for small amounts derived from condenser leakage and evaporator carryover, up to the point at which treating chemicals in the form of sodium salts may be ordinarily added. Therefore, the use of potassium in place of sodium salts will result in a boiler water in which the ratio of potassium to sodium is quite high, and controlling.

In those plants in which the makeup is treated by zeolite softeners, the substitution of potassium chloride for sodium choride in the process of regeneration affects the result so that the softener may be run to substitute potassium for sodium, as well as for calcium and magnesium. This, of course, applies to zeolite softeners operated on the sodium cycle. In the case of softeners run on the acid cycle, neutralization of the treated water with potassium hydroxide or other alkaline potassium salts will supply a feedwater which in many instances will contain the required amount of potassium to establish satisfactory potassium equilibrium in the boiler water.

If the softening operation is of the lime-soda type, the substitution of potash for soda ash will considerably increase the ratio of potassium to sodium in the water.

In conclusion, the author observed that, while more laboratory and field data are still needed, he is confident that a logical approach to the problem has been made.

Heat Rates for Theoretical Regenerative Steam Cycle

A paper by A. M. Selvey and P. H. Knowlton offered a simple tabular-integration method for calculating heat rates for a theoretical steam cycle with an infinite number of heaters regenerating feedwater to throttle saturation temperature and taking into account the work of the boiler feed pump. A tabulation of theoretical heat rates was included for throttle conditions ranging from 300 to 3200 psi absolute and for saturation temperatures up to 1200 F and an absolute exhaust pressure of 1 in. of mercury. Provision was also made for calculating heat rates at other exhaust pressures within the wet-steam region.

The purpose of the heat rates so determined is to provide a standard for measuring power-plant performance, and as a first step in estimating regenerative-cycle economy at unfamiliar steam conditions. Typical examples were included showing the application of dèsign and performance factors to these theoretical regenerative-cycle heat rates for three actual power plants.

At the time of preparing the paper, the authors had not had the opportunity to derive all that is necessary for complete economic estimates, but they hope to do so in a subsequent paper. Meantime, existing plant records can be made to provide approximate factors that can be used. An appendix contained full directions for using the tables.

Combustion-Control Methods

In a paper entitled "New Combustion-Control Methods for All Standard Fuels," Robert Reed pointed out that if two or more fuels are burned in combination, the recorded CO_2 will have little value unless the precise volume of each fuel is known and Orsat analysis is made to find the true condition of excess air. Reviewing the theory of combustion, the author stated that combustion of hydrocarbons proceeds as a race between hydroxylation and thermal decomposition according to type of fuel and manner of burning. A clear flame indicates hydroxylation and a luminous flame indicates thermal decomposition, but neither denies the presence of the other. If the true condition of combustion is to be found, means of indicating presence of soot, aldehydes and free H_2 might be necessary in addition to CO_2, O_2 and CO.

The author, whose experience has been with oil- and gas-fired furnaces, cited an installation employing 10 per cent excess air with a 0.55-sp gr natural gas, in which errors resulting in inefficient combustion were due to the inability of the Orsat to show aldehydes in the flue gas, and a leak in the sampling line which allowed sufficient O_2 to appear in the sample to check against the H/C ratio, by weight of the fuel. He stated that, in the field, checking for CO is merely a formality usually recorded as "zero per cent" but that these remarks did not apply to the burning of coal and coke. Even where coal is burned, combustion efficiency is not fully indicated by the CO reagent, since volatile elements burn partly by hydroxylation, and unburned substances other than CO can readily appear in the flue gases

It was also noted that a certain concentration of O_2 in the flue gases indicates almost exactly the same excess-air factor for any fuel or combination of fuels from natural gas to coke within the limits of analysis and observation. O_2-excess-air relationship is independent of the CO_2 concentration which would change with variations in the H/C ratios, by weight. The CO_2 is, therefore, relegated to the provision of a means of checking flue-gas analysis against the H/C ratio of the fuel or fuels. Two sets of curves on "Excess Air by CO_2" and "Excess Air by O_2" were given for consideration and use in the field. Positive means for detecting the presence of aldehydes in the flue gases were also given. In conclusion, it was pointed out that the aldehyde test is really a double check which may save a great deal of fuel and also mechanical difficulty with the furnace.

Burning Barley Size Anthracite

Allen J. Johnson, of the Anthracite Industries, Inc., presented a paper entitled "The Combustion of Barley Size Anthracite," which discussed the supply and qualities of this fuel and the operating conditions necessary to burn it.

Due to the increased demand for domestic sizes, the production of barley anthracite now greatly exceeds consumption demands, and substantial stock piles are

available at low cost to the plant owner with suitable burning equipment. Grates recommended include stationary or dump grates having a pinhole mesh not over $^3/_{16}$ in., "semi" or hand stokers with inclined grates having 8 per cent slotted air space $^5/_{64}$ in. wide, also chain and traveling grates. Where stokers or "semi" stokers are used, proper arch and furnace design are necessary,

Curves were given showing the draft differential required between furnace and ashpit for Nos. 1, 2 and 3 buckwheat at different combustion rates; also curves showing that the heat value is inversely proportional to the ash content and that there is a drop of only 2 per cent in overall boiler efficiency over the entire range of ash contents.

Uniformity of sizing is most important in the burning of barley size anthracite. Resistance to flow through the fuel bed rises rapidly with more than 20 per cent undersize. Furthermore, the character of the fines is as important as the percentage, as serious difficulties are likely to ensue if undersize is almost all dust. A certain percentage of moisture (probably as high as 4 per cent) is deemed useful in tempering the fuel. With anthracite, moisture is merely a surface condition which may be readily drained and dried.

With both hand firing and "semi" stokers, $2^1/_2$ in. is a proper static pressure below the grate when delivering the rated quantity of air. With traveling grates, maximum air pressures usually do not exceed $1^1/_2$ to 2 in. When forced draft is available, it is customary to balance it against the pull of the stack or induced draft, but it should never be below 0.05 in. Drafts in excess of 0.10 in. carry an unnecessary amount of heat to the stack.

The author discussed the different types of burning equipment and intimated that the prime rule in firing any size of anthracite is—"Leave it alone." However, firing barley size anthracite is no job for a janitor. But, considered as an abundant and satisfactory fuel which is not affected by priority delivery orders, any investment in equipment adapted to its use will amply reward the plant owner in subsequent fuel economies.

Fuels and Fuel Research in Great Britain

W. C. Schroeder, of the U. S. Bureau of Mines, reviewed the present fuel situation in Great Britain and the consequent planning as fostered by the war, including certain long-range research problems that have been undertaken.

Since all liquid fuel must be imported, with the exception of small amounts produced from low-temperature distillation, oil shale, and coal hydrogenation, the situation is much more acute than in the United States. All pleasure driving is banned, and gasoline can be obtained only to go to work in essential industries when the distance traveled is greater than two or three miles and no public transportation is available. These limitations led to casting about for other means of automotive propulsion, with gas stored in bags on top of cars, liquefied gases, and portable gas producers such as have been employed extensively in Germany, France and Sweden. However, although gas producers using wood charcoal have proved very successful in these continental countries, Great Britain is limited in wood supply, hence has turned to the development of producers employing anthracite or high-temperature coke.

In the matter of coal production, the output of British mines, measured in terms of tons per man-day, is much lower than that in the United States, due to less mechanization, thinner seams, older mines and different mining methods. When a manpower shortage in the mines threatened earlier in the war, all miners were frozen to their jobs and registration was made of all men not engaged in mining but who had previously worked in mines for at least six months since 1935. Of the latter, those not physically disqualified or who were not engaged in more important war work, were returned to the mines—a total of about 20,000 to 25,000. When these measures did not suffice to meet increased production demands and replace losses from natural causes, another 20,000 miners were returned from the armed forces; and, finally, draftees between the ages of 18 and 21 were permitted to choose between the army and the mines.

The shortage of coal in Great Britain has resulted in a vigorous fuel-economy campaign directed at both residential and industrial consumers. This is administered by a Fuel Efficiency Committee guided by a National Advisory Committee composed of twelve prominent fuel engineers. The program includes the appointment of an engineer in each individual plant or company who is held responsible for adopting fuel economy measures and who is assisted by fuel watchers throughout his organization.

Research work to convert coal to oil and gasoline started in Germany about 1913 and it is now believed that from one-half to one-third of Germany's war requirements for gasoline come from that source. On the other hand, the production of synthetic liquid fuels was slow in getting started in Britain and it was not until about 1935 or 1936 that such a plant was put in successful operation by Imperial Chemical Industries. But, despite the success of this plant, there was no further commercial development of coal hydrogenation in Great Britain, apparently because it was cheaper to import gasoline and oil.

Among the long-range research projects now under way are (1) studies to estimate the inner surface of coal through measurement of the heat of wetting, using methyl alcohol as the wetting agent; and (2) an investigation of the fundamental nature and properties of coal through the reflectance of light from polished coal surfaces.

Uses for Fly Ash

The economical disposal of fly ash to a market that will absorb vast quantities such as are produced by large central stations has been the subject of numerous studies for several years, one of the leaders in such studies being The Detroit Edison Company. In a paper entitled "An Evaluation of the Importance of Physical and Chemical Properties of Fly Ash in Creating Commercial Outlets for the Material," C. M. Weinheimer of that company told of laboratory and field investigations with a view to modifying the fly ash to meet commercial specifications.

Carbon, aluminum and silica constitute approximately 90 per cent of the content of fly ash, but recovery of aluminum from this source could not compete with other existing methods. In brief, it seems impractical to sell fly ash on the basis of its chemical characteristics; hence its potential outlets depend upon physical characteris-

tics. The hollow glass-like spheres as revealed by microphotographs indicate some possibility of use in thermal insulation and there are other possibilities for use as a filler in rubber; but the principal outlets for bulk requirements seem to be with asphalt in bitumastic pavement material and to reduce the cement content in concrete. Many pavements in and about Detroit have long been using large quantities and a light-weight cinder concrete has been developed in which $4^1/_2$ bags of cement, 150 lb of fly ash and 36 gal of water per cubic yard of concrete are employed. This is especially adaptable to building construction and has shown excellent results. The fly ash improves the workability of concrete.

One difficulty encountered has been the seasonal use for such applications in view of the constant production of fly ash. To overcome this, a large storage silo has been erected at the Marysville Plant of the Company. Handling of fly ash in bulk is usually accomplished by cement cars or special trucks with Fuller-Kenyon pumps for loading and unloading.

In response to a question from the floor, Mr. Weinheimer stated that the selling price of fly ash varied over a wide range, depending upon the quantity involved, but that, generally speaking, about a dollar a ton profit made its disposal worth while.

Boiler Fan Selection and Use

A symposium on "Boiler Fan Selection and Use," under the sponsorship of the Power Division, was made up of contributions by H. F. Hagen of B. F. Sturtevant Company and M. S. Kice of American Blower Corporation, representing fan manufacturers; P. S. Dickey of Bailey Meter Company, who dealt with control; W. S. Patterson of Combustion Engineering Company, representing the boiler manufacturers' viewpoint; and J. J. Grob of Consolidated Edison Company and L. M. Exley of Long Island Lighting Company, representing users.

Mr. Hagen led off the discussion with the criticism that, although fans are designed and tested to conform to their characteristic performance curves, they are often selected on the basis of certain assumed factors and consequently are frequently operated at points off the curve, with consequent loss in efficiency and power. He further expressed the opinion that much mechanical power could be saved if forced-draft fans only were to be employed in stationary plants just as is done in marine practice.

Mr. Kice discussed the application of radial, forward- and backward-curved blade fans and the relative wear under various conditions with each type, the location of dampers and the necessity of providing ample foundations. He cautioned against running water-cooled bearings too cool and advocated temperatures of 120 to 130 F. It was his opinion that more latitude should be left to fan manufacturers in interpreting specifications.

Mr. Dickey reviewed the various types of fan drive and control, pointing out relative advantages and limitations, and stated that too much consideration is sometimes given to power economy. He recommended variable-speed drive for large units down to about 40 per cent of maximum speed and damper or vane control below this.

Mr. Patterson showed how it is practically impossible to test a fan under actual service conditions, hence pressure and volume tolerances are necessary in making the selection. He reviewed the various sources of infiltration such as air-heater leakage, infiltration through duct-expansion joints, burner boxes, damper-rod openings, walls, etc. Also, with stokers, the resistance through the fuel bed varies and with pulverizers the tempering air represents an additional quantity. Altitude and outside temperature also are factors. Such considerations make it necessary to establish certain tolerances that cannot be accurately figured and which must be based on experience. Furthermore, service conditions often make it necessary to operate off the fan characteristic curve.

Notch-Toughness Tests of Carbon-Molybdenum Pipe

Development of materials for high-temperature steam piping is of considerable importance in view of the upward trend in power-plant operating temperatures. Chemical composition, steel-melting practice, and heat-treating procedure, and their effects on physical properties and microstructure are factors in appraising the probable behavior of a material in service. The metallurgist and the power-plant designer are particularly interested in the influence of these factors upon notch-toughness of the material.

On the premise that there may be some correlation between notch toughness and performance of high-temperature pipe, and that significance should be attached to the interpretation of notch-toughness with respect to the behavior of carbon-molybdenum pipe material for power-plant service, Messrs. W. F. Kinney, I. A. Rohrig and H. S. Walker presented the results of an investigation at the Detroit Edison Company laboratory on notch-toughness testing.

The specific problem studied was to determine the influence on the uniformity of test results and on the magnitude of average notch-toughness values, both at room temperature and at 925 F, of the type of specimen, the heat of steel, and its condition. It was believed that, in addition to the physical-strength tests commonly conducted on carbon-molybdenum pipe material at either room temperature or elevated temperatures, the notched-bar test should appeal to producers and consumers, both from the standpoints of results obtained and of economy, simplicity and expediency.

Combustion in High-Pressure Chambers

This paper, by E. G. Peterson, dealt with present practice in this country in employing direct-fired air heaters with pressures of 45 to 55 psi gage, or higher, and heat releases of 500,000 to 2,500,000 Btu per cu ft per hr in connection with catalytic refining processes in the oil industry. These processes employ high-temperature combustion air up to 900 or 1000 F and a gas turbine to drive the compressor.

In this connection he described in detail the direct-fired refractory-lined air heaters and fuel oil and gas burners as are being built by Peabody Engineering Corporation. He observed that while his paper was confined to the design and application of equipment for the refining field, another important application which is now being considered is that of ship propulsion by gas-turbine-generated power.

Addition to Capacity and Modernization of

MARYSVILLE POWER HOUSE

The first of this series of articles in the October issue, brought out that space for the initial addition to capacity of the Marysville Plant was provided partly by extending the existing plant at the end toward the river and partly by removal of some of the old equipment in that end of the plant adjacent to the new extension. Plans for further increases in capacity, when that becomes desirable, call for progressive removal of more of the old equipment in the original plant and replacement by new equipment of larger capacity, duplicating that installed in the first step of the expansion program. The present article discusses the foundations, the selection of fuel-burning equipment, and describes in detail the steam-generating units and their appurtenances. The next article of the series is scheduled for February.

By **H. E. MACOMBER**
The Detroit Edison Company

As PREVIOUSLY stated, the foundation of the existing plant is a boat-type concrete mat resting directly on the clay surface without pile support. During the past twenty years this foundation, reacting true to form according to experience in this area, has settled in the shape of a saucer as shown by the settlement contour lines of Fig. 8. It will be noted that the center of the saucer is about 5 in. below its original elevation, whereas toward the edges of the mat the settlement becomes progressively less. While movements of this character and magnitude have in no way affected the operation of the plant, it was believed inadvisable to cause any increase in the rate of settlement. It followed, therefore, that the loading per square foot on the clay beneath the old plant should not be increased and that the loading under the extension should not be greater than that under the original plant.

A difficult problem in connection with the new foundation resulted from the fact that test borings and shear tests showed the presence of a 12-ft thick surface stratum of very soft clay in the location to be occupied by the extension of the turbine house. This stratum probably acquired its poor quality from having been in contact during the life of the plant with water flowing in the intake and overflow canals. It was feared that vertical pressure from the weight of the boiler- and turbine-house extensions, acting like a piston, would create conditions favorable to sub-soil movements resulting in upheaval of the soft clay into the canals.

To prevent such movement, a wall of steel sheet piling was driven around the periphery of the turbine house extension and the upper end of the piling was embedded in the concrete mat which, like the original mat, rests on the surface. To reinforce this wall against outward bending, additional sheet piling was driven at frequent intervals and at right angles to the wall to form a series of ribs around the inside of the enclosure. The edges of these ribs adjacent to the wall were locked to it. In addition, individual sheet piles were driven under the bearing walls in the turbine house. All of this piling was of sufficient length to pass through the soft clay stratum and well into the stiffer clay below. As a further precaution, the mat for the boiler-house extension was constructed with a toe wall along the end facing the river.

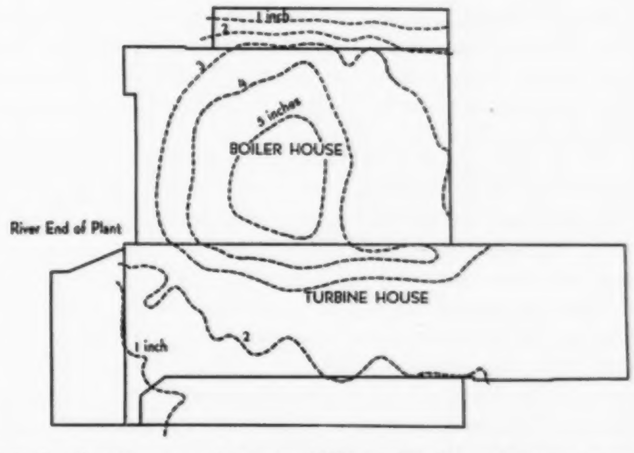


Fig. 8—Settlement of original Marysville foundation; contour lines represent the locus of settlements of the magnitude indicated

The purpose of this arrangement was to keep vertical pressure off the 12-ft stratum of soft clay and to prevent lateral movement, but at the same time to avoid supporting the new foundation more rigidly than the old because it was desired that it should have about the same final rate of settlement as the old. Calculation of the number of square feet of sheet piling required to accomplish this end was based upon tests of the shear value of the clay at various depths.

To compensate for the comparatively rapid initial settlement anticipated for the plant extension, the base plates for the steel of the superstructure were set $1^1/_2$ in. higher than the present elevation of the base plates in the adjoining part of the existing plant. Six months later the new foundation was found to have settled $^{13}/_{16}$ in., and during the following ten months an additional settle-

ment of $^2/_{16}$ in. was recorded. Thus, the extension at the end of 16 months had settled a total of $^{15}/_{16}$ in. and was roughly only $^1/_2$ in. in elevation above the old plant. This is considered quite satisfactory and it is believed that the final rate of settlement of the extension will come close to matching that of the original building.

Selection of Fuel Burning System

The decision that soil loading at the Marysville site should not be increased over the original value was an important consideration in studies of the fuel-burning system to be adopted for the new steam generators. Another factor of importance was the column spacing in the old boiler house since one of the new steam generators involved in the first step was to occupy the position of an existing old boiler; also, plans for future capacity increases called for the replacement of more old boilers with new steam generators, duplicates of those installed in the first step.

The original boiler house with its two rows of double-end stoker-fired boilers was served by three rows of coal bunkers, a center and two side rows. Each center bunker, serving a battery of two boilers on opposite sides of the firing aisle, had a capacity of 500 tons and each of the side bunkers serving one boiler had a capacity of 250 tons. Thus each boiler had the equivalent of 500 tons of bunker capacity.

Preliminary studies indicated that to accommodate a new steam generator of required capacity in the position previously occupied by an old boiler, and within the existing column spacing, it would be necessary to remove the side coal bunker. This automatically ruled out the use of the double-end-type stoker but did not eliminate the consideration of the long single-end stoker of the type installed at the Delray Plant.

As to pulverized fuel, this method of firing called for the installation of the heavy electrostatic-type flue dust collector but, on the other hand, stoker firing at the high rates of combustion common in modern steam generators also involves the need for some type of cinder collector if stack discharge nuisance is to be avoided. One advantage of pulverized fuel was its greater flexibility with respect to the types of coal that could be burned. However, aside from all these considerations, comparison of the two methods from the standpoint of weight showed that only with the pulverized fuel system could the limitation on soil loading be met. This, therefore, became the deciding factor in favor of pulverized fuel.

Steam Generators

In the design of the Marysville steam generators, considerable attention was given to the matter of tube spacing and to proportioning of heating surface between the furnace, superheater and other heat-absorbing parts in an effort to minimize slagging and fouling tendencies. Special attention was also given to means for cleaning the heating surfaces during operating periods to avoid the need of taking the unit out of service for such purposes. As a result, it is believed that it will be possible to operate these steam generators from one annual overhaul period to the next without shutdown, and experience thus far seems to justify this belief.

A sectional elevation of the new steam generator is shown in Fig. 9. It is a natural circulation unit having a continuous full load capacity of 440,000 lb per hour. The boiler and superheater are designed for a maximum working steam pressure of 975 psi. Pressure at the outlet superheater header to give the design pressure of 815 psi at the turbine throttle is 865 psi. In addition to the water-cooled furnace, the unit includes a three-drum, bent-tube type of boiler with integral superheater and economizer. The furnace walls and ceiling are completely covered with water tubes and the ash hopper at the bottom is covered by a water-tube hearth screen. The rear wall water tubes are extended to the top of the furnace to form a tube screen in front of the superheater which consists of a semi-radiant and a convection section. The normal flue gas path is through the rear tube screen, the radiant and convection sections of the superheater, the convection boiler tubes, and thence to the economizer. Outlet superheated steam temperature is controlled in part by adjustment of a flue-gas diversion damper which extends across the width of the boiler and which, when open, allows the combustion gases to bypass most of the convection section of the superheater and the convection boiler tubes. This damper is actuated by an air-operated power cylinder, the control for which is located on the boiler-control panel. Manipulation of this control is a manual operation.

An open-pass flue-gas duct with built-in venturi metering throat for measurement of flue-gas flow connects the economizer outlet with twin regenerative-type air heaters. From the air heaters, the flue gases pass through the electrostatic flue dust collector to the induced-draft fan and then to the stack.

Twin forced-draft fans, located above the steam generator and close to the induced-draft fan, draw air from the fan room and discharge it to the air heaters. From here it is led through down-ducts to the burner casings and the pulverizer mills. Continuing the Company's past practice and, because of the availability of direct current, the forced- and induced-draft fans are driven by adjustable speed direct-current motors. The induced-draft fan motor, shown in Fig. 10, is rated at 900 hp, with field regulation from 700 to 300 rpm and armature resistance regulation from 300 to 240 rpm. The forced-draft fan motor, visible in part in Fig. 11, is rated at 400 hp with field regulation from 1000 to 500 rpm and armature resistance regulation from 500 to 250 rpm. Field regulation for each forced- and induced-draft fan motor is accomplished by pilot-motor operation of the field rheostat. Armature resistance speed regulation of each motor is accomplished manually at the motor starter control.

Fuel-Burning Equipment

The pulverized-fuel system used is the direct-fired type, there being two mills for each steam generator. The pulverizers, shown in Figs. 12 and 13, are roll-type bowl mills each mill together with its exhaust fan being driven by a 250-hp, 440-volt constant-speed, a-c motor. Coal for each mill is conducted by gravity chute from the bunker to an adjustable-speed motor-driven feeder located on the operating floor. From the feeder the coal passes to the mill at a rate governed by the speed of the feeder. Each mill has a rated capacity of 24,100 lb per hour when grinding coal having a grindability factor of 50 and moisture content of 10 per cent, to a fineness of 70 per cent through a 200-mesh sieve. Preheated air mixed with the proper amount of room air to keep the

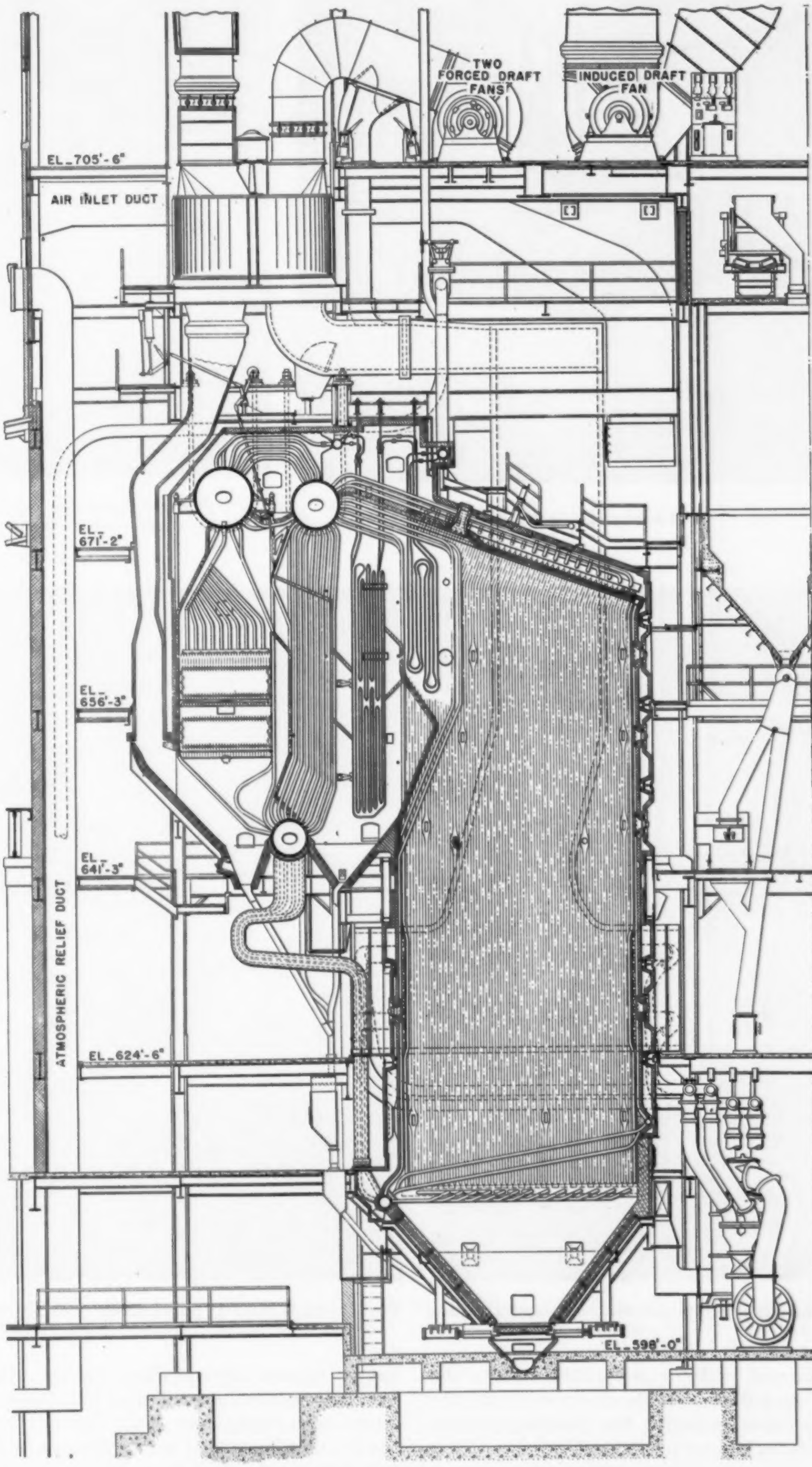


Fig. 9—Sectional elevation of new C. E. steam generator

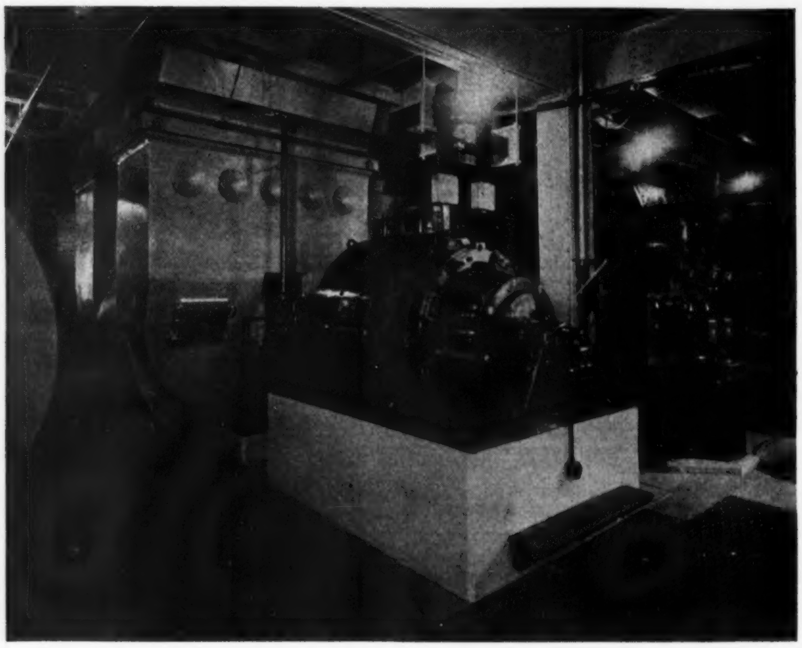


Fig. 10—Induced-draft fan motor

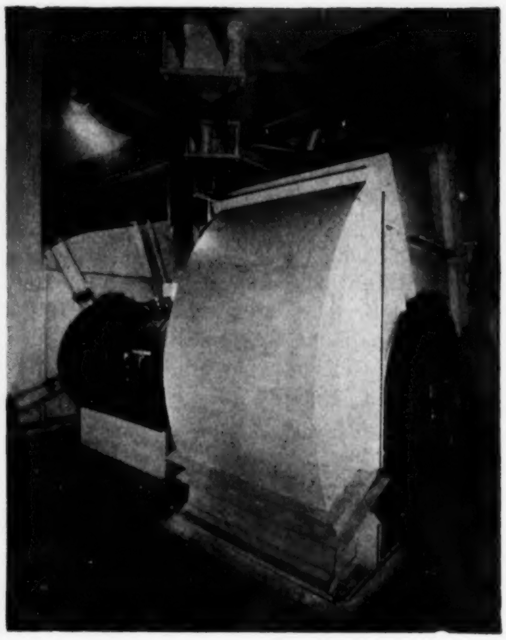


Fig. 11—Twin forced-draft fans driven by a single motor

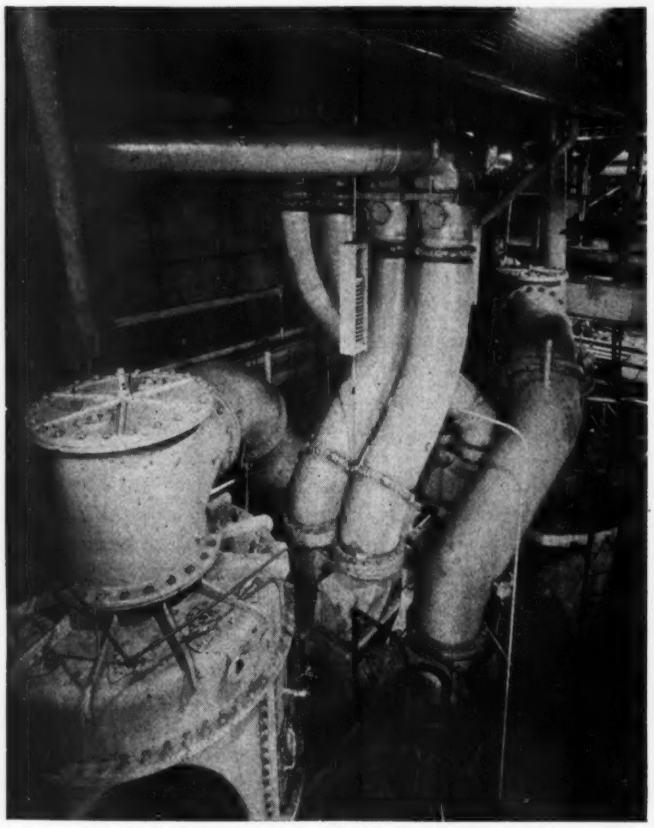


Fig. 12—Coal-pulverizing mills, showing transport piping

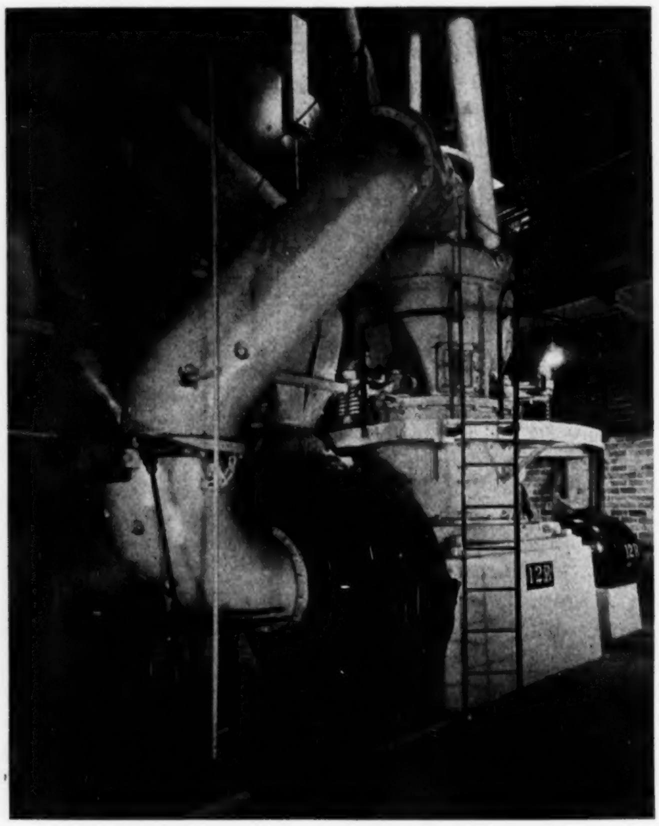


Fig. 13—Side view of pulverizing mill, showing exhaust fan

temperature of the mill within safe limits is drawn into the pulverizer by the mill fan. This air serves to dry the coal, size the coal particles during the grinding process, and transport it through pipes to the coal burners. Here the air serves as primary combustion air.

There are two coal burner nozzles at each corner of the furnace, located one above the other. The top burner in each corner is supplied with coal from one mill and the lower burners are supplied by the other mill. As a means for controlling superheated steam temperature, in addition to adjustment of the flue gas diversion damper, the nozzle of each coal burner is made adjustable through a vertical angle of 60 deg—30 deg above and 30 deg below the horizontal. That is, the burner nozzles can be tilted in a vertical plane thus moving the flame path downward or upward in the furnace. Under a given set

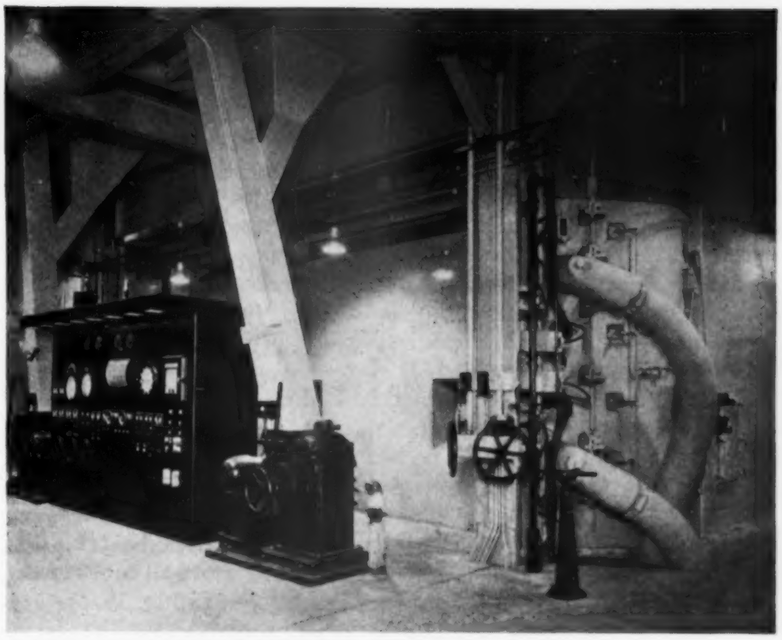


Fig. 14—View showing burner casing at corner of steam generator and also main gage board and coal feeders

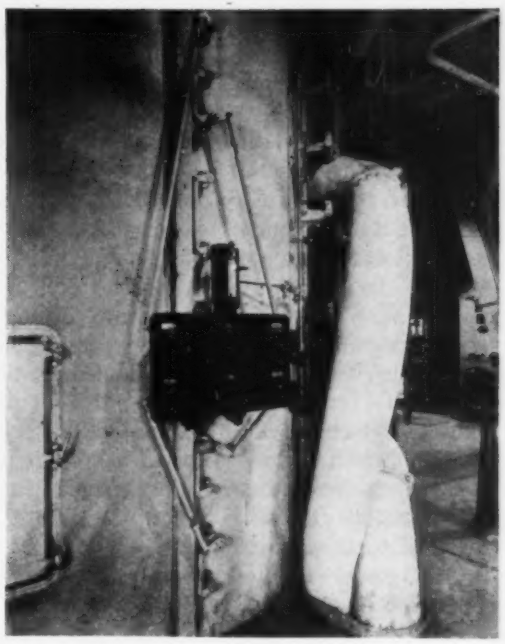


Fig. 15—Secondary-air damper adjusters

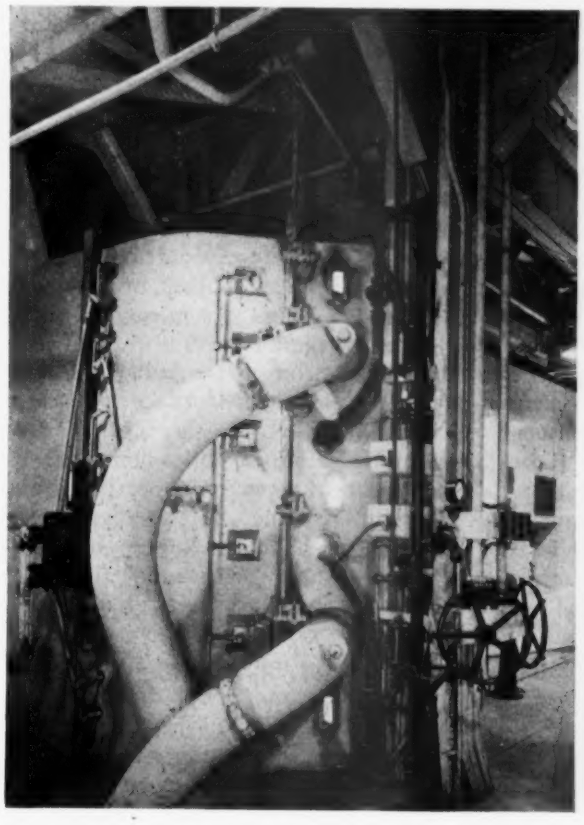


Fig. 16—View of burner casing showing piping and guardcocks for gas torches

Fig. 17—View inside the furnace facing the rear wall and showing openings in the corners for the burners

of conditions the full 60-deg adjustment of the burner nozzle angle results in a change in superheated steam temperature of about 40 F. Adjustment of the angle of the burners is accomplished by a linkage system actuated by an air cylinder, the manual control for which is located on the boiler gage board.

Figure 14 shows the burner casing at one corner of the furnace. The coal feeders supplying coal to the mills can be seen at either end of the gage board and the pulverized fuel transport pipes leading to the two burners in the casing are also evident. The preheated-air duct can be seen alongside the burner casing. Fig. 15 shows the manually operated secondary air damper adjusters. The dampers are located in the burner casing and are positioned through the linkages shown.

Means for lighting the coal burners is provided by per-

manently installed, non-retractable, electrically ignited gas torches which are supplied with gas piped from the Company's commercial gas plant on the Marysville property. There is one torch for each coal nozzle, making a total of eight torches. The torches for the top coal nozzles are located just below these nozzles and are controlled as a group. Those for the bottom coal nozzles are located above these nozzles and are controlled as another group. Gas piping to the torches can be seen in Fig. 16. In the supply line to each torch, and close to the point where the piping passes into the burner casing, here is a guard cock operated by an air cylinder which, in turn, is controlled by a solenoid-operated pilot valve electrically interlocked with the ignition circuit. Thus the guard cock is automatically opened when the ignition switch is closed but when voltage is removed for any reason from the ignition circuit, the guard cock automatically closes. The ignition circuit for the upper group of torches controls only the guard cocks on those torches, guard cocks on the lower group of torches being controlled by the ignition circuit for that group.

The gas for all torches of the same steam generator is supplied from the plant gas main through a single connection in which there is a manually operated control valve with a floor-stand extension which can be seen in Figs. 14 and 16. The flow of gas to the torches is regulated by this valve. In bringing a boiler up to pressure the torches may be used merely for the purpose of lighting the coal burners, but they are designed with a capacity to burn enough gas to bring a boiler to line pressure within five hours without using the coal burners.

The ignition switches for the upper and lower groups of torches can best be seen in Fig. 14. They are mounted on the column to the left of the burner casing and are equipped with pilot lights to show on and off positions from a distance.

The coal used at Marysville comes principally from the mines of West Virginia and eastern Kentucky. This coal as received has the following typical analysis:

	Per cent
Fixed carbon	53.10
Volatile matter	34.00
Ash	8.65
Moisture	4.25
	100.00
Sulphur, from ultimate analysis	1.00
Btu per lb, as received	13,200

Boiler and Furnace

The width of the furnace inside the tube walls is 24 ft and the distance from front to rear tube wall is 21 ft. The height of the furnace from the hearth screen at the bottom to the roof tubes, measured at the center of the furnace, is approximately 53 ft. Furnace volume is 27,830 cu ft including the space below the hearth screen. A view of the interior of the furnace facing the rear wall is shown in Fig. 17. This picture was taken during construction and openings in the corners of the furnace to take the burners are evident.

All furnace-wall tubes are 3 in. OD and are spaced on $3^1/_8$-in. centers, forming a tangent tube-wall surface. Adjacent tubes in the front and side walls are bifurcated at the top and the bottom, each pair terminating in a $3^1/_2$-in. tube. The terminal tubes, which are on $6^1/_4$-in. centers, are expanded into square steel headers at the top and bottom of the furnace. The headers are $5^1/_2$ in. square inside and $^7/_8$ in. thick. The back wall tubes in the lower half of the furnace are also spaced $3^1/_8$ in. on center and are bifurcated at the bottom, the terminal tubes being $3^1/_2$ in. OD and entering a 12-in. ID header on $6^1/_4$-in. centers. As shown in Fig. 9, in the upper part of the furnace, some of the rear wall tubes are arranged to form a two-row screen in front of the semi-radiant superheater, the remainder of the tubes passing up behind that section of the superheater, and all tubes entering the lower steam drum of the boiler. To accomplish this arrangement, every other rear wall tube is brought forward, half of these forming the row nearest the fire and the other half forming the row nearest the superheater, the tubes in each row being in line, that is, not staggered. The center-to-center dimension in the two rows is $12^1/_2$ in. giving a clear passage between the tubes of $9^1/_2$ in. The center-to-center distance between the tubes of the single row behind the superheater is $6^1/_4$ in. The general appearance of the rear wall tubes in the upper part of the furnace can be seen in Fig. 17.

The tubes forming the hearth screen at the bottom of the furnace are 3 in. OD and extend on $6^1/_4$-in. centers from the bottom front-wall header to the 12-in. header at the bottom of the rear wall; alternate tubes form the top row of the screen, the remaining tubes forming the bottom row. Thus, the rows are staggered and center-to-center distance between tubes of each row is $12^1/_2$ in. The furnace roof tubes, extending from the top front-wall header to the lower steam drum of the convection boiler, are $3^1/_2$ in. OD finned tubes spaced on $6^1/_4$-in. centers. It can be seen in Fig. 9 that the side-wall headers at the top of the furnace follow the pitch of the furnace roof. Because of this inclination these headers are equipped with baffles forming a series of separate compartments, each accommodating two $3^1/_2$-in. entrance tubes, or two pairs of 3-in. bifurcated side-wall tubes. From each of these compartments a $3^1/_2$-in. OD plain tube fans out and connects with the lower steam drum of the boiler. These tubes form two layers parallel to the furnace roof, each layer entering the steam drum at $12^1/_2$-in. centers. Between these layers and the finned tubes immediately below, there is a layer of refractory. Connections from the lower side-wall headers to the 12-in. header at the bottom of the rear wall form a similar pattern and offer added screening effect to the hopper bottom. The bottom side-wall headers, being horizontal, require no baffles.

The internal diameter of the upper steam drum of the boiler is 60 in. and that of the lower steam drum is 48 in. The lower drum of the boiler is of 36-in. inside diameter. The approximate length of each, including heads, is 30 ft, 3 in.; 29 ft, 9 in.; and 26 ft, 9 in., respectively. All drums are fusion-welded, the welds being stress-relieved and X-rayed. The drum shell plate for the 60-in. drum is $2^3/_8$ in. thick, except at the tube ligaments where it is $2^{23}/_{32}$ in. thick. Corresponding dimensions for the 48-in. drum are $2^3/_{16}$ and $2^5/_8$ in., whereas the thickness of the 36-in. drum shell is $1^{31}/_{32}$ in. throughout. All boiler heat-transfer tubes are 3 in. OD. The total effective heating surface of the furnace tubes is 7098 sq ft and that of the convection boiler is 6575 sq ft.

Fig. 18 shows diagrammatically the circulatory path of the whole steam generator. All water supplied to the wall headers and tubes is carried first to the 12-in. header

at the bottom of the back wall by sixty-four $3^1/_2$-in. OD down-take circuit tubes *H* from the 36-in. drum. From the 12-in. header, water is distributed directly to the rear wall tubes *E*, to the bottom side-wall headers through tubes *G*, and to the bottom front-wall header through tubes *F*. All flow from the furnace tubes is into the 48-in. drum of the boiler. Circulation through the convection boiler tubes is generally downward as indicated.

Drum Steam Washer and Baffles

The 60-in. or main steam drum of the boiler contains a bubble-type steam washer shown in Figs. 19 and 20. Steam entering the drum through the circulator tubes from the 48-in. drum is directed by a tight baffle plate to

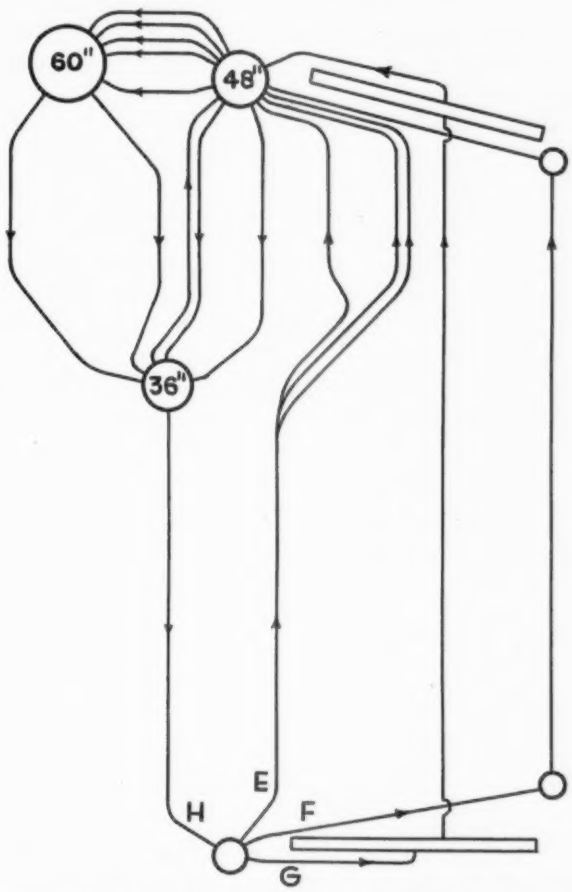


Fig. 18—Circulatory path in the steam generator

a series of small steam hoods located at $3^1/_4$-in. intervals along the feed pan. Each steam hood is 1 in. wide and 11 in. long and has a number of $^3/_8$-in. diameter discharge holes in the side plates near the bottom. The hoods are positioned so that the holes are below the level of the water in the feed pan. Steam, in escaping through the holes, is forced, therefore, to bubble through the incoming feedwater. The washed steam is passed through the rod-type dryer on its way to the superheater.

As indicated in Fig. 19, baffle plates in the 48-in. steam drum are arranged in a manner tending to separate the steam from the water. An important feature in connection with the operation of the boiler is the throttling effect of the steam-conducting tubes connecting the 48-in. and the 60-in. steam drums. This effect is accomplished by using fewer than the usual number of tubes and the restriction tends to hold a somewhat higher pressure in

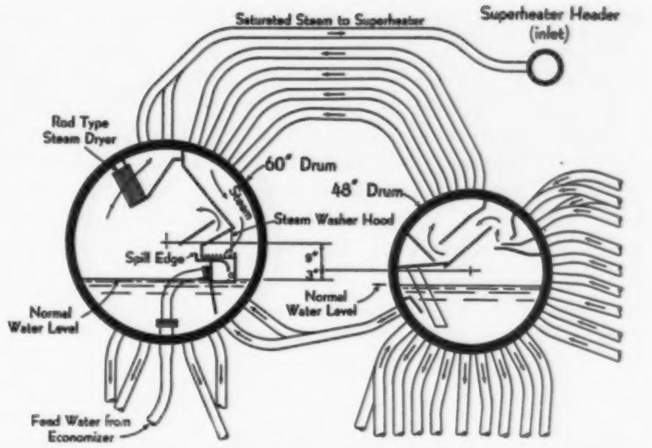


Fig. 19—Steam washer and dryer in 60-in. drum and baffle in 48-in. drum

the 48-in. drum which in turn holds the water in that drum at a slightly lower level than that in the 60-in. drum.

Superheater

Saturated steam is led from the 60-in. steam drum through forty 3-in. OD tubes to the low-carbon steel inlet superheater header which is $10^3/_4$ in. OD and has 1-in. walls. The primary or convection section of the superheater is made up of ninety $2^1/_8$-in. OD low-carbon seamless steel elements on $3^1/_8$-in. centers, there being twelve rows front to back of the bank with the tubes in successive rows—one directly behind the other; that is, not staggered. In the secondary or semi-radiant section, $2^1/_8$-in OD chrome-molybdenum-titanium stabilized seamless steel tubing is used and here the ninety elements are intermeshed to give a center-to-center dimension of $6^1/_4$ in. with successive rows of tubes directly behind one another. Thus, across the width of this bank, which is the same as the width of the convection bank, there are only 45 rows of tubes. The elements of this section are welded to those of the convection section at a point near the roof of the furnace as shown in Fig. 9. To avoid the need for welding the dissimilar metals

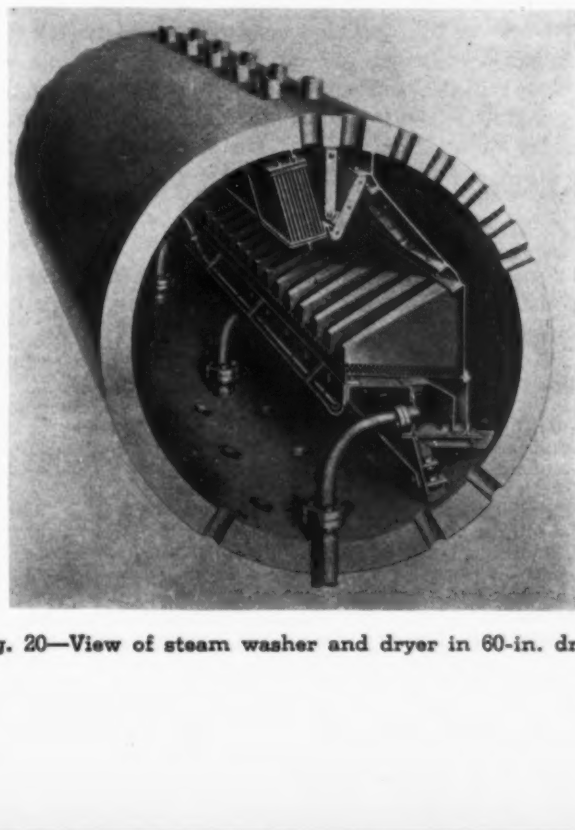


Fig. 20—View of steam washer and dryer in 60-in. drum

in the field, short pieces of carbon-molybdenum tubing were flash-welded in the manufacturer's shop to the abutting ends of the tubes of each section so that welding during erection was between the carbon-molybdenum ends. The outlet superheater header is carbon-molybdenum steel, $10^3/_4$ in. OD with $1^1/_8$-in. walls. The total effective heating surface of the convection section of the superheater is 13,393 sq ft and that of the semi-radiant section is 2589 sq ft, giving a combined total of 15,982 sq ft.

Based on a feedwater temperature of 375 F and specified excess air, and with proper manipulation of the flue-gas diversion damper and adjustment of the burner-nozzle position, the superheater was designed to maintain an average steam temperature of 910 F $\pm$ 10 deg F over a range of load from 225,000 to 480,000 lb of steam per hour. Actually, this performance, as to range of load, has been surpassed for it has been possible with only one mill in operation to regulate the steam temperature within $\pm$10 deg F of the design temperature at loads as low as 150,000 lb of steam per hour. The design steam temperature at the turbine throttle is 900 F.

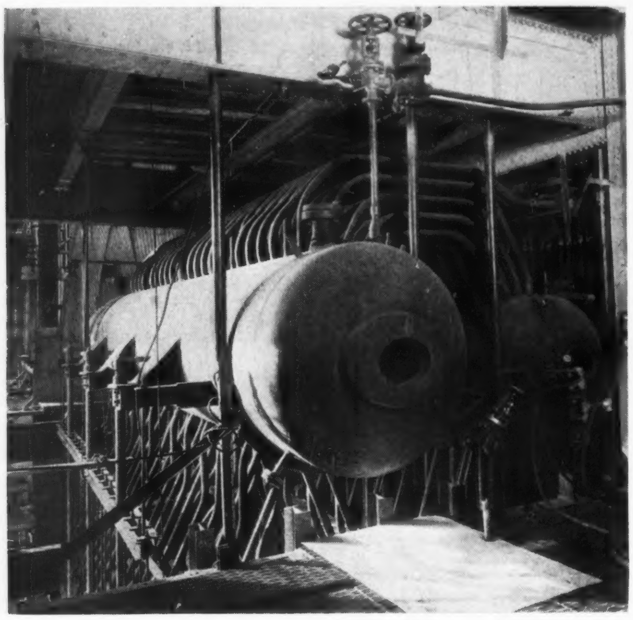


Fig. 21—View of top of boiler during erection showing brackets on 60-in. steam drum which holds the economizer-suspension tubes

Economizer

The finned-tube economizer for each steam generator is constructed according to the following general description:

Type	Horizontal fin-tube
Gas flow	Down through economizer
Water flow	Up through tubes
Number of tubes wide	32
Number of tubes high	14
Horizontal spacing	3-in. centers
Vertical spacing	5-in. centers
Size of tubes	2 in. OD
Gage of tubes	No. 7 B.W.G.
Length of tubes between return bends	23 ft, 5 in.
Fin size	2 in. wide, $^1/_4$ in. thick
Total effective heating surface	12,136 sq ft

The location of the economizer is apparent in Fig. 9. There are two banks of tubes, one above the other, and each contains seven horizontal rows, successive rows being staggered.

The inlet and outlet headers are made of 1 in. thick seamless tubing, the former $10^3/_4$ in. OD and the latter $8^5/_8$ in. OD. The tubes were field welded to nipples which were welded to the header in the manufacturer's shop. One $8^5/_8$-in. OD, $^5/_8$ in. thick, connection at the center of length of the inlet header admits the feedwater to the economizer. From the outlet header ten 3-in. OD, 0.280 in. thick, tubes fan out and enter the bottom of the 60-in. steam drum on 25-in. centers. Inside the drum these tubes are flange jointed to short tubes which terminate in the feed pan or distributing trough from which the water spills into the drum over a toothed wier plate. (See Fig. 20.)

The weight of the economizer is supported, as shown in Fig. 9, by six $3^1/_2$-in. OD, 0.400 in. thick, water-cooled suspension tubes, three on each side. The lower ends of these tubes are rolled into the 36-in. boiler drum and the top end of each tube is held by a bracket welded to the 60-in. drum. In these brackets the tubes terminate in a welded cap closure from which there is a 2-in. connection into the drum at an elevation above the normal water level. This arrangement is shown in Fig. 21. The supporting tubes thus form a part of the boiler circulatory system.

The material used in the various pressure parts of the unit conform to the following specifications:

Item	A.S.M.E. Specification No.
Boiler Drums	S-55, Grade B
Boiler- and Furnace-Wall Tubes, (Low-carbon seamless steel)	(The Detroit Edison Company, Specification No. 295, April 30, 1937)
Superheater Tubing,	
(a) Carbon-molybdenum-titanium	S-52, Symbol T16
(b) Carbon-molybdenum (Connecting semi-radiant and convection sections)	S-48, Grade T1
(c) Low carbon	S-17, Grade A
Saturated Steam Header	S-18
Superheated Steam Header	S-45
Water-Wall Headers	S-18

Air Heaters

Each steam generator is equipped with two Ljungstrom regenerative-type air heaters located side by side directly over the boiler and below the fan-room floor. (See Fig. 9.) The flue gas duct, beyond the economizer outlet, divides into two branches, each leading to one of the heaters. The hot gases pass upward through the gas section of the heaters and then to the flue-dust collectors. Air from the forced-draft fans passes downward through the air section of the heaters and thence through the preheated air ducts to the furnace.

The height of the heating elements of the circular rotor of each heater is 56 in. and the housing is designed to accommodate additional elements to a total height of 70 in. The present heating surface of each heater is 41,800 sq. ft. In operation, a 5-hp d-c motor rotates the heating element of each heater at a constant speed of 3 rpm, thus continuously bringing the surfaces heated by the

flue gases into the air compartment where they give up their heat to the cold air delivered by the forced-draft fan.

At a load on the steam generator of 440,000 lb of steam per hour, design temperatures entering and leaving the heaters are: for flue gas, 695 F and 340 F, and for air, 100 F and 585 F, respectively.

Cold Air Bypass

Low loads on the steam generator are, of course, accompanied by low temperatures of the gases entering the air heaters. Under these circumstances, and depending in part upon the temperature of the incoming air, the heater elements, in passing through the air section of the heater, may be cooled to such an extent that, when they pass into the gas section, they will cool the flue gases to a temperature below the dew point. This condition is most likely to occur in the upper part of the heater where the elements are in contact with the coldest air and the coolest gases. Any moisture condensing on the elements will create conditions favorable for corrosion, principally because of the sulphur products in the flue gas. In addition, however, the moisture would tend to induce fouling and plugging of the spaces between the element plates which could result in a shutdown of the steam generator.

To avoid these conditions a cold air bypass is provided for each air heater. Its function is to reduce the amount of cooling experience by the elements in passing through the air section of the heater. This is accomplished by shunting part of the combustion air around the heater and in this manner the temperature of the gas leaving the heater is kept above the dew point. The arrangement of the bypass is shown in Fig. 9. It consists of a separate duct branching off the main duct between the forced-draft fan and the heater and joining the preheated-air duct on the downstream side of the heater. There are two dampers at the entrance to the bypass, one swinging into the bypass duct, and the other swinging into the main duct. These dampers are operated in sequence, the former or primary damper, opening first, followed by the opening of the latter or secondary damper which acts as a deflector vane to scoop additional air into the bypass if it is necessary to suit the existing condition. The primary dampers in the two bypasses serving a single steam generator are operated together and likewise the two secondary dampers are operated together. The secondary dampers are not moved from the closed position until the primary dampers are at full open position.

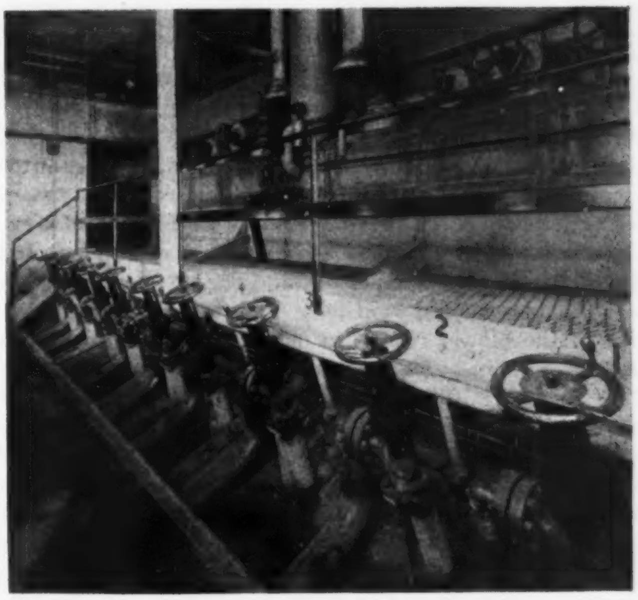


Fig. 23—View of retractable oscillating soot-blower operators

It has been found that, in general, the arithmetic mean of the sum of the outlet gas and inlet air temperatures approximates the actual metal temperature of the upper or cold end of the heater element at the time it passes from the air section to the gas section of the heater. As a control medium, then, an instrument which will total the inlet air and outlet gas temperatures can be used as a guide to regulate the quantity of air to be bypassed around the heater to maintain a margin of safety between the coldest element temperature and the dew point of the flue gases. At Marysville a totalizing pyrometer controller is used for the purpose and the dampers are automatically regulated by linkages actuated by compressed-air-operated power cylinders.

Soot Blowers

Three types of soot blowers are used on the Marysville units: retractable oscillating blowers, rotating blowers and fixed blowers, as indicated in Fig. 22. All use saturated steam.

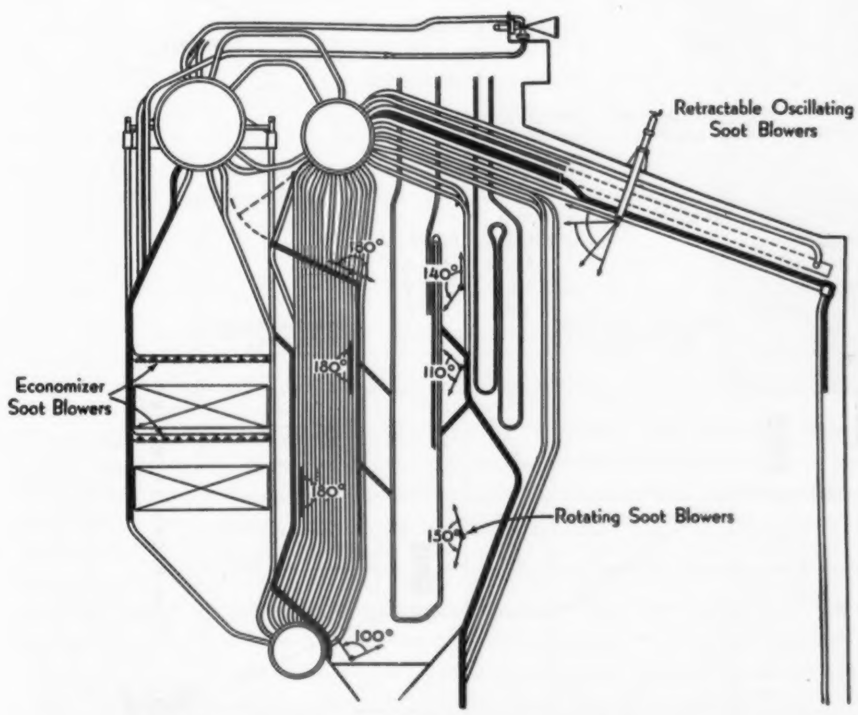


Fig. 22—Location of soot blowers in steam generator

The retractable blowers are located at ten points across the width of the furnace roof as shown in Fig. 23. Operation of the handwheel moves the blower nozzle downward 8 in. to a point slightly below a line tangent to the lower surface of the roof tubes. Just before the nozzle reaches the end of its downward travel, the steam valve automatically opens and the nozzle makes a horizontal sweep of 75 deg across the tubes. When the handwheel is reversed, the nozzle makes a sweep back to its original direction, the steam shuts off, and the nozzle moves upward to its retracted position. Thus one complete operation of the blower results in one sweep across the tubes and back again. The nozzle of every other one of these blowers is set so that the jet is directed toward the lower portion of the semi-radiant superheater bank and the jets of the remaining blowers are directed toward the upper portion of that tube bank. These ten jets, therefore, cover the upper part of the two rows of furnace tubes in front of the superheater as well as the semi-radiant superheater itself. The steam supply for these blowers is taken from the main steam drum and the piping is such as to provide a pressure at the nozzle during blowing of about 750 psi.

The rotating soot blowers consist of independent horizontal tubes extending from opposite locations in the two side walls to almost the center of the setting. Nozzles are located at $6^1/_4$-in. intervals along the length of the tubes. It will be seen from Fig. 22 that these blowers are located so as to clean the convection superheater and the convection boiler tubes. Steam is supplied from the 200-psi saturated steam header serving the plant.

The fixed blowers, designed and constructed by the Company, are located above each of the two banks of economizer tubes. They consist of transverse headers with nozzles so arranged as to blanket the tubes thoroughly during the blowing period. Steam supply for these blowers is taken from the main steam drum but the piping is such as to give a nozzle pressure of the order of 300 psi.

The present schedule of operation of the blowers calls for one blow during each 24-hr period, except that the five retractable blowers directed at the lower portion of the superheater are blown one day and the remaining five are blown the next day.

The air heaters, as installed, are provided with fixed blowers furnished by the manufacturer. Steam for these blowers has been piped from the 200-psi saturated steam header but, to date, there has been no need to use these blowers regularly. The regenerative-type air heater is more or less automatically cleaned in service by the passage of the elements through the air section of the heater, provided, of course, that no moisture deposits on the elements as a result of cooling the flue gas below the dew point.

Safety Valves and Feedwater Regulator

There are three safety valves on the main steam drum of each steam generator and two on the outlet superheater header. All of these valves are spring-loaded and self-actuating. Fig. 24 shows the pressure settings both in tabular and graphic form.

One 6-in., two-element boiler-feed regulator with hy-

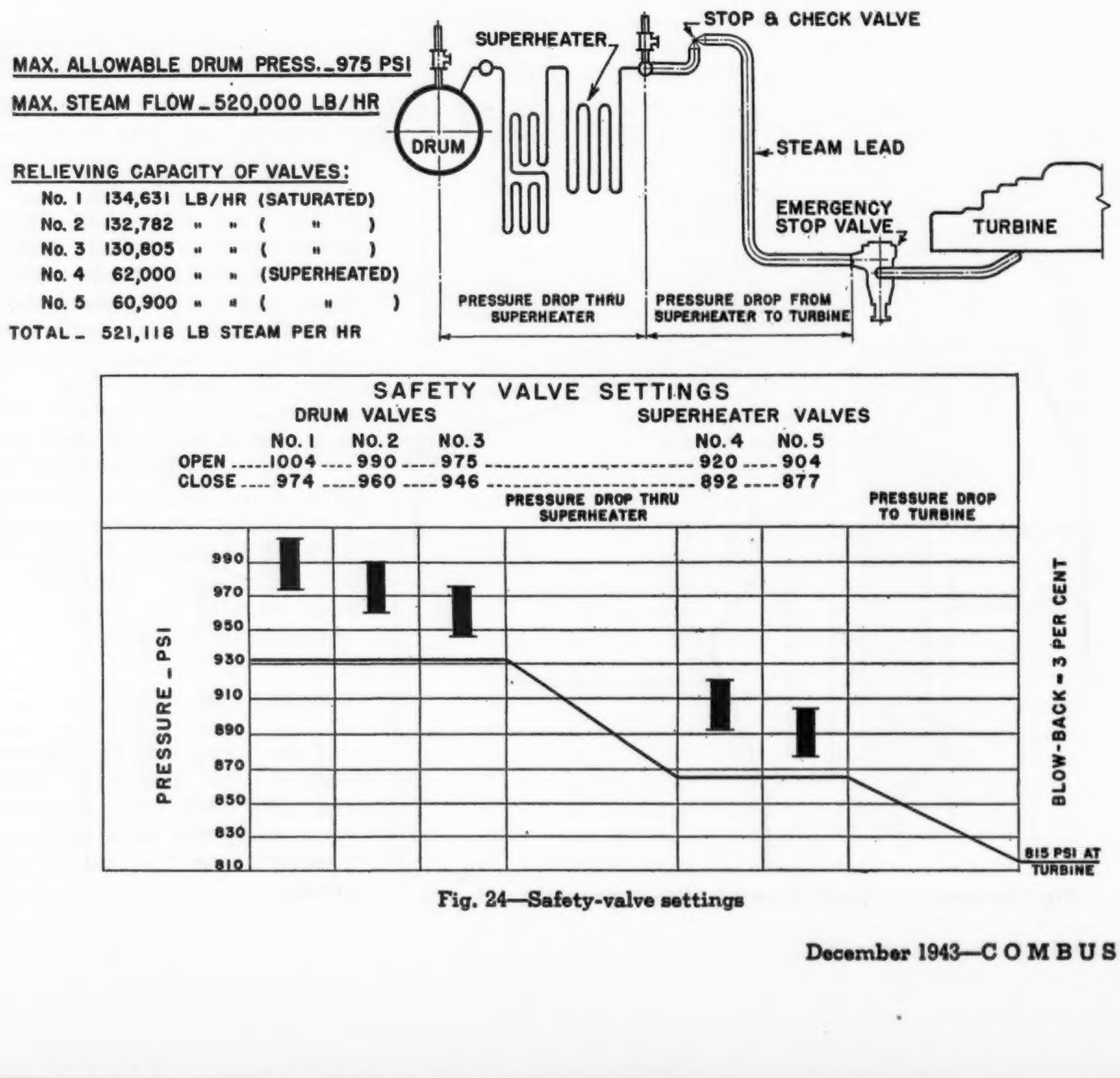


Fig. 24—Safety-valve settings

draulically operated valve is installed on each steam generator. The valve, shown in Fig. 25, is located in the feed line to the economizer. The hydraulic medium used for controlling the action of the valve is condensate supplied at a constant pressure from a head tank.

The demand for feedwater is made primarily a function of steam flow, measured by the differential pressure across the superheater, and secondarily a function of the water level in the 60-in. steam drum. At a steaming rate of 440,000 lb per hour, the water pressure drop through the

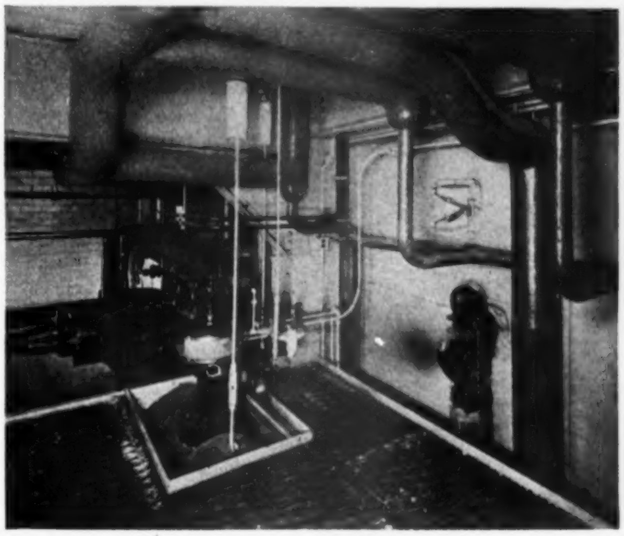


Fig. 25—Hydraulically-operated feedwater regulator valve

economizer is 20 psi and the steam pressure drop through the superheater is 66 psi, or a total of about 86 psi. Under this condition, with a feedwater header pressure of about 1100 psi and a pressure of 865 psi at the superheater outlet, the pressure difference across the regulator valve is of the order of 150 psi.

For manual regulation of feedwater there is a 6-in. globe valve in a bypass around the regulator valve. During manual operation an 8-in. gate valve in the line just ahead of the regulator is closed so that all flow to the boiler is through the bypass. Both the 8-in. gate valve and the 6-in. globe valve are operated by means of handwheels located on the building column at the right of the main boiler-control panel on the operating floor. (See Figs. 14 and 16.) To the fireman facing the column, the wheel on his right controls the 6-in. globe valve and that on his left controls the 8-in. gate valve. Control wheels on all units are in the same relative position.

Winter Inlet for Combustion Air

In cold weather, when boiler-house doors and windows are kept closed as a matter of personal comfort, the entrance of combustion air by infiltration may cause uncomfortable draftiness as well as extra load on the fans. Depending upon the tightness of the building structure and the amount of combustion air required, the differential between the pressure outside and inside the building may reach a value of one inch of water or more. Because of this, two fresh-air inlet ducts have been installed in connection with each new steam generator. These ducts draw air through openings in the building wall just below the fan-room floor. Each wall opening has an area of 20 sq. ft. Several feet from the building wall the two ducts join and terminate in a plenum from which the air enters the boiler room through dampered openings at a point above the furnace roof. The air then passes upward to the forced-draft fans through gratings and stair openings in the fan-room floor.

Instrumentation of Steam Generator

In selecting instruments and controls for the steam generators, it was the aim to keep them to a minimum in the interest of simplicity but, on the other hand, to provide all that were essential for complete and convenient supervision of operation.

Each unit is provided with a main instrument and control panel which can be seen in Fig. 14 and a closer view of which is shown in Fig. 26. In addition to this panel, controls for the gas torches and for manual regulation of feedwater, as previously described and shown in Figs. 14 and 16, are located on the building column to the right of the main panel. On this column is also located a mechanical operator to position the tempering air damper at the air inlet to one of the mills. A similar control for the other mill is located on the building column to the left of the main instrument and control panel. Adjusters for the secondary air dampers, which were shown in Fig. 15, are located on each burner casing.

The main control panel is 12 ft long and 7 ft, 8 in. high. On it are mounted indicating steam- and water-pressure gages, draft gages, temperature recorders for air, flue gas, feedwater and steam, the feedwater level recorder, a steam-flow meter, and combustion-control equipment. The indicating draft gages are of the diaphragm type.

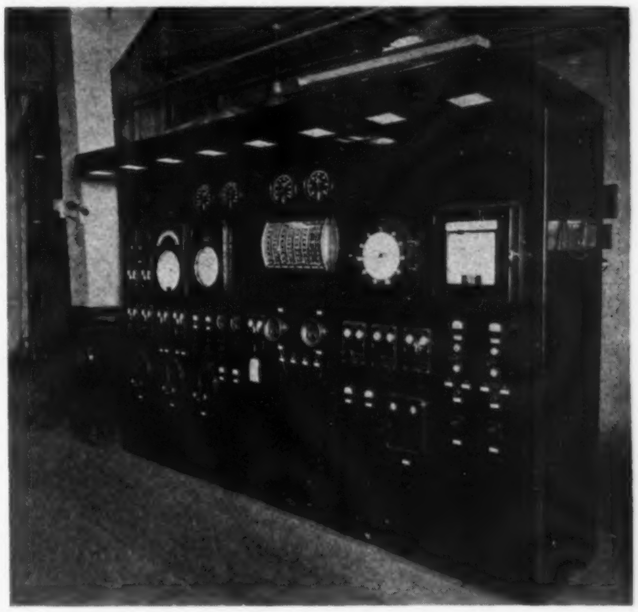


Fig. 26—Main instrument and control panel for steam generator

Two types of temperature recorders are used, one a multiple-point strip chart instrument which periodically records all temperatures except that of the superheated steam. The latter temperature, because of its importance for control purposes, is recorded as a continuous line on a circular chart recorder. Both instruments operate on the potentiometer principle using thermocouples as the sensitive elements.

Single stage, double suction pump with motor drive
Motor-mounted pump
Six stage centrifugal pump driven by electric motor
Section of De Laval-IMO oil pump
Steam turbine driven boiler feed pump
Clogless pump
DE LAVAL Products
Mixed-flow pump
Opposed impeller pump
Worm gear
Steam turbine driving alternator
Multistage compressor driven by multistage turbine
Flexible coupling
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Dust Collectors Constructed of Non-Critical Materials*

Faced with a directive from the War Production Board for the omission steel, as a critical material, in the construction of internal parts of fly-ash collecting equipment, studies were undertaken toward the substitution of ceramic materials. The results of this investigation are reviewed and adopted design is described.

By LOUIS C. WHITON

President, Prat-Daniel Corporation

DUE to the critical nature of steel during the present war, a serious problem was presented to industry throughout the entire United States. Certain types of apparatus, which had been determined by good engineering practice as a necessary part of industrial operations, had to be eliminated wherever it was possible. Apparatus for the collection of dust is, of course, essential in many industrial operations, and it has rapidly become an integral part of most modern power plants. It is true that in previous years dust was not removed from flue gases, and it was hoped, therefore, that it would not be necessary to remove dust from such sources during the war period, thus economizing the steel necessary for the building of such dust collectors. This did not prove to be entirely true, however.

In April 1942, the War Production Board issued directives recommending the omission of all internal parts of fly-ash collecting equipment in land boiler installations for the duration of the emergency, in order to economize in the use of critical steel. This apparently was not capable of being followed completely because it was evident that there were various war plant operations which required clean atmosphere in the neighborhood of such plants, and imperative for the protection of the plant equipment and products, from injury due to fly ash returning to the plant by eddy currents in the atmosphere and reversal of wind direction.

Therefore, an extensive questionnaire was sent out by the writer's company to various war plants, to learn whether it was considered that dust collectors were essential for the operation of such plants. A large number of replies were received, over ninety per cent of which concluded that such dust collectors were necessary.

The amount of steel used in a dust collector varies considerably with the type. The three mechanical types are:

1. Apparatus used in connection with a fan as part thereof.
2. A multicyclone type, consisting in a number of cyclones from 2 to 5 ft in diameter.
3. The tubular type, consisting of a large number of small centrifugal tubes of about 6 in. diameter.

* From a paper presented before the Metropolitan Section, A.S.M.E., New York, on November 16, 1943.

A study was started immediately upon receipt of the directive from WPB and at its suggestion, to find means of substituting other material than steel in connection with this type of apparatus. It was evident from the start that the approach should be on the use of ceramic material, since the supply of this raw product was unlimited, and it was probable that it would never be considered a critical product.

The writer's company manufactures all three types of dust collectors mentioned above, but the first type, where the apparatus was combined with the fan, was discarded as a possibility for the application of ceramic-

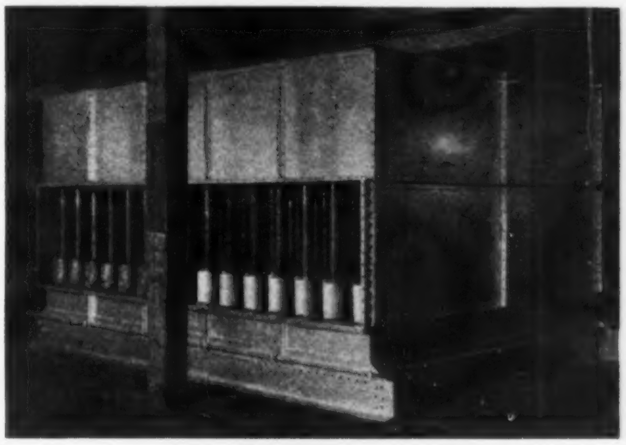

Fig. 1.—Group of steel tubes between tube-sheets

ware in place of steel, since the parts would be relatively large, and the ceramic manufacturers did not feel that this was commercially feasible to manufacture with their material.

The multicyclone type was also discarded for the same reason, and the application was, therefore, determined to be most practical when using small diameter tubes, since the units could be made with a minimum of joints, and the type of manufacture was similar to that which has been practiced for many years by manufacturers of ceramic-ware, namely, pipes and tiles. In addition, the amount of special apparatus required for its production was a minimum.

In the steel tubular type the tubes were $6^5/_8$ in. diameter for the main centrifugal tube, and $4^1/_2$ in. diameter for the central or gas outlet tube. The inlets to the tubes for the gas were composed of heavy steel plate

welded to an upper and a lower disk. Each tube, depending upon the operating conditions, handles in the neighborhood of 250 to 300 cfm of gas, and the tubes are placed normally between tube sheets, as shown in Fig. 1. These welded sections, each containing approximately 50 tubes are then joined at their flanges and form the tubular dust collector. The gas enters the main section between the two tube sheets and is rotated within the tube after it enters the flared inlets. Thus the dust is precipitated by centrifugal force, and the clean gas issues through the $4^1/_2$-in. tube to a point above the upper tube sheet, whence it passes to the fan or to the atmosphere.

In general accordance with the original directive of WPB, the problem was studied so as to utilize ceramic tubes set in steel tube sheets. However, a subsequent request on the part of the Board to save in the use of steel, indicated the advisability of using non-priority material throughout. Therefore, the final design consisted of fire-clay ceramic tubes, reinforced-concrete tube sheets, and brick or reinforced concrete side walls.

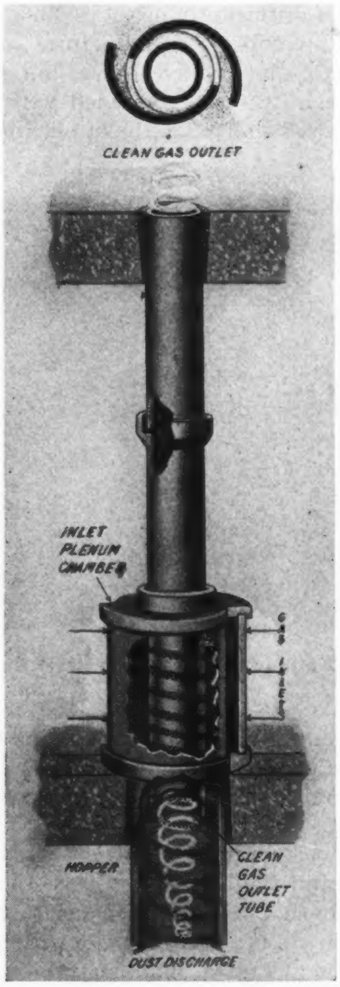

Fig. 2.—Partially cut-away section of ceramic tube

Our engineers set up definite specifications to cover a ceramic tube that would meet the following conditions:

1. High dust collecting efficiency.
2. Resistance to erosion and corrosion.
3. Ability to withstand the shock of rapid temperature changes.
4. Ability to withstand fluctuating temperatures up to, and sustained at or above 600 F.
5. A design that could be manufactured by existing clay-working plants and machinery when supplied with special dies.
6. A design, the component parts of which, may be easily assembled in the field.
7. To produce a ceramic tube that may be used equally well in either a steel casing or a non-priority materials housing or casing.
8. A ceramic tube that must meet specifications 1 to 7, inclusive, and be sufficiently rugged and sturdy to withstand the hazzard of handling, transportation and erecting, with a minimum of breakage.

To produce ceramic tubes that would meet these specifications required a careful study of the properties and characteristics of various fire clays, bonding clays

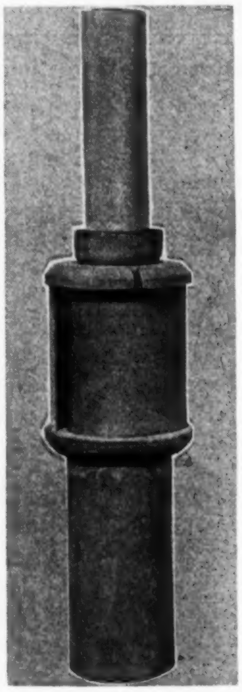

Fig. 3.—Exterior view of single ceramic tube

and other aggregates, a combination of which, when properly processed, would be a product meeting those specifications.

It was soon discovered that we were pioneering in the production of a ceramic product that had no parallel in refractory ceramics, and our consulting engineer secured the assistance of high-class ceramic technicians who have had well-seasoned experience in manufacturing refractory ceramic specialties.

The Ceramic Tube

The lower portion of the tube shown in Fig. 2, consists of a $6^1/_2$ in. tile with a flanged top, in which has been impressed recesses for holding the wings or flared inlets to the tube. These wings are a heavy curved tile of a special form required for this apparatus, and the tile may be made as thick and sturdy as required, since it is the internal diameter that matters. This is then capped by a companion flange, identical with the flange on the lower tube, and containing the same

recesses, into which the flared inlet wings are fitted. The central $4^1/_2$-in. tube is similar in shape to standard clay tiles, and this may be extended upward to any required distance by additional tubes. Fig. 3 represents an exterior view of an assembled ceramic tube of the design adopted.

The problem then arose as to the method of handling such dust-collecting units in the field. A special cement was developed by the tile manufacturer, composed primarily of the same material from which the tubes are made. This is used to cement the tiles together in a jig. Its chemical reaction starts in 25 min, and when the tube is removed from the jig, it can be handled normally without any of its parts coming apart. The strength is indicated by the fact that aside from the weight of the tube itself, which is practically 60 lb,

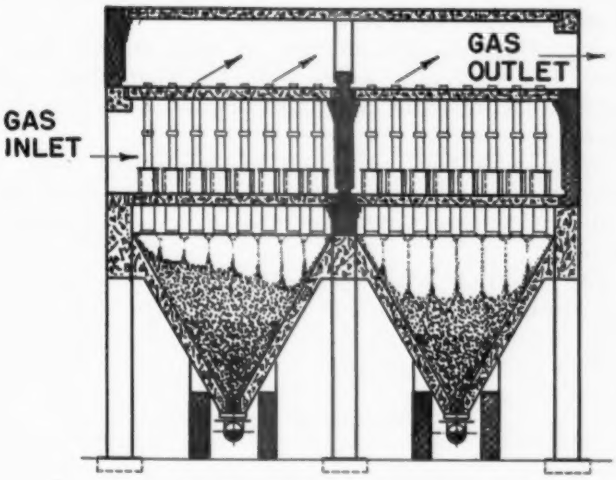

Fig. 4.—Single-deck arrangement

it required an additional weight of 115 lb on the bottom of the tube to pull any of the joints apart when the tube was held from its upper end.

Such tubes are shipped in knocked down condition, in carefully prepared crates, and it has been found in practice that the breakage is extremely small. These tubes are then rapidly set up in the jig at the site of the installation, which is then removed, and the tubes are allowed to set twenty-four hours. They can then be handled by workmen without fear of having their parts separate, and they can be set in either steel tube-sheets, to which they are cemented with the same material, or into concrete tube-sheets for the ceramic unit. The $4^1/_2$-in. gas outlet tube is arranged with a slip joint to allow for expansion.

The specifications for the manufacture of the tube require that it have a coefficient of expansion of approximately 0.000005, and that it be capable of withstanding a temperature range from 0 to 600 F within a period of two hours without fracture due to expansion or any other reason.

Concrete as Tube Sheets

In order to determine the suitability of concrete for tube sheets in temperatures such as are encountered in boiler plant practice, a careful study was made of past experience in this use. Of course, it was known that it has proved satisfactory to use concrete for baffle walls of electrostatic dust collectors.

John L. Graham, consulting engineer, who is a specialist in the use of concrete and ceramics, was employed to investigate not only the tube material, but also the use of concrete for the tube sheets. During World War I, when steel was also considered a critical material, he had designed reinforced concrete tops and bottoms for boiler flues. His specialty at that time was in connection with wood product plants burning wood refuse in their boilers. Those familiar with this fuel know that there is frequently secondary combustion and carryover of fine wood particles in the gases. Also, such plants which use a waste product, do not have any necessity for heat economy devices, and in consequence the flue gas temperature in the average plant is much higher than in the usual boiler plant.

An installation at Tupper Lake, New York, which was equipped with six 400-hp Sterling boilers, had been built with such reinforced concrete flues in 1916 and 1917. The smoke flue at that plant is 88 ft long, 7 ft wide on the interior and 12 ft deep. The reinforced concrete slab floor is 6 in., and the roof is 5 in. in thickness. That plant has been in continuous operation for approximately 25 years, and to date no repairs of any kind have been made on this flue although the flue gases reach 700 to 750 F.

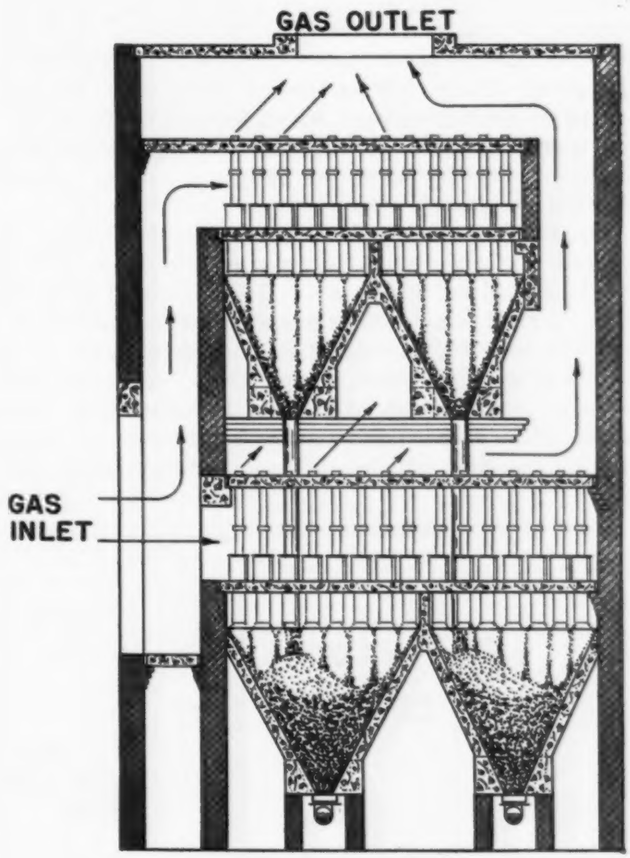

Fig. 5.—Double-deck arrangement

This same construction was used in a plant at Bay City, Mich., for three large boilers, the flues being 6 ft wide and 30 ft long; for another plant at Boyne City, Mich., with two 250-hp boilers; and still another plant

at Saginaw, Mich., for two 300-hp boilers having a flue 20 ft long and 6 ft wide.

After a careful observation of these installations it was deemed entirely feasible to utilize this type of construction for the tube sheets of a tubular dust collector.

Further investigation was made in connection with one of the large cement manufacturers, who reported as follows:

1. Heavier sections of concrete are more heat resistant than thin sections.
2. A small amount of dehydration occurs on the surface when the concrete is in contact with flame, and the surface skin thus produced is a better insulator than normal concrete, retarding dehydration at a greater depth.
3. Concrete cured for long periods is more heat resistant than concrete which has been cured for relatively shorter periods; 28-day curing or drying out is preferred.
4. Limestone or blast-furnace slag aggregates give greater resistance than do natural siliceous aggregates. Lime-carbonate in limestone acts as an insulator.
5. Crushed firebrick used to replace part of the aggregate materials produce good results when concrete is in direct contact with flame.
6. Special portland cements do not show any advantage over normal portland cements.
7. The baffle walls in cement kilns are frequently constructed of concrete, and in the plant of the engineer reporting it was found that even at temperatures as high as 1400 F many months' use can be expected. These baffle walls are constructed of normal portland cement and slag aggregate.

Specifications for the reinforced-concrete are extremely strict, and follow closely those used by the consulting engineer in the construction of the concrete tops for flues installed twenty years previously and still in operation. These call for the use of the best grade of American portland cement, which must be fresh and live, and which has not been exposed to dampness or other conditions which might be injurious to its setting qualities.

The concrete made therefrom shall also withstand without cracking, temperature rises from 0 to 600 F over a period of two hours. The sand used must be hard, sharp crystal, such as disintegrated or crushed red or black granite. Specifications are given also as to the fineness of the sand, which must be entirely free of loam, silt organic matter and particularly from tannic acid. Consequently, such sand must not come from a sand bank which is beneath hemlock, cedar, oak or other surface growth that might produce tannic acid seepage into the sand. If such tannic-acidfree sand is not available, fines from crushed hard granite or trap-rock may be used in its place.

For the crushed stone or granite used in the mix, only hard granite, hard lime stone, dolomite or trap-rock may be used. Sand-stone is not acceptable. Special instructions are given as to the exact sizing of the crushed stone used in the aggregate. The degree of mixture is important. In 96 lb of the portland cement, exactly $2^1/_2$ cu ft of sand and $3^1/_2$ cu ft of crushed rock are used. The proper mixing with water is also important.

Even transportation from the mixer to the job must be done with care, so as to not disturb the homogeneous condition of the concrete mass. Consequently, the use of chutes between the mixers and forms is not acceptable. Prevention from possiblity of freezing for a period of at least 21 days must be exercised.

Special designs of reinforcing are used, and the forms must be practically water tight, so that there will not be a loss of water in certain portions of the concrete mass.

As an additional protection to the cement itself, a layer of fire clay may be flowed over the top of the cement tube sheet after the tubes have been installed therein.

The question of proper expansion under heat is taken care of by using slabs which are held on corbels, thus permitting the slab to expand without coming in contact with the side walls.

Space Conditions

The space required for the ceramic type of dust collector, if arranged in single deck, is greater than for the steel tubular dust collector. This is due to the fact that the exterior dimensions of the tube are greater, to allow for the greater thickness of the ceramic tube over the steel tube, and the exterior walls are thicker than steel. In other words, the tubes cannot be placed as close together as is possible with the steel tubing. This arrangement is shown in Fig. 4. This may be overcome from the standpoint of area occupied, by utilizing the double deck arrangement shown in

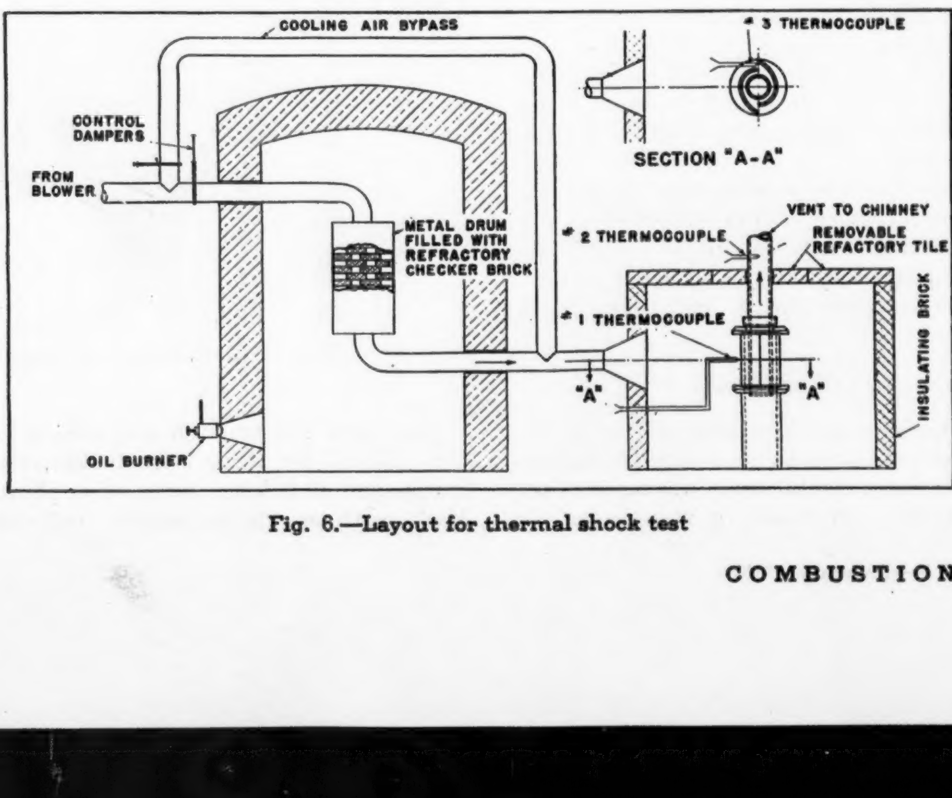

Fig. 6.—Layout for thermal shock test

Fig. 5. The floor area of this unit will, of course, be considerably less than the floor area of a single-deck steel tube arrangement, but the height will be greater. It will be noted in this method that the gas is allowed to enter the upper and lower deck, to pass out of the center tubes to a common chamber leading to the gas outlet. The hoppers of the upper section lead immediately to the lower hoppers, and are not used for storage of dust themselves. This double-decked arrangement has been used extensively with the steel tubes in the past. It also forms convenient support for the induced-draft fan or a combination fan and stack. Of course, the fan can be placed on top of a single-decked arrangement, but some height of stack is saved by utilizing the double-decked system such as shown herewith.

Another interesting layout, which was developed by one of the boiler manufacturers, incorporated the dust collector as a part of the structure for the coal hoppers.

Weight of the Ceramic Tubes Compared with Steel

The actual weight of each tube, exclusive of the rest of the structure, is approximately the same as the steel tube, since the specific gravity of the fireclay is about one-third that of steel. For large installations of dust collectors it is preferable to utilize this system in a structure from the ground up, either inside the building or outside. If the latter method is used, considerable building space may be saved over that which would have been necessary, even with a steel collector inside the building.

This temperature-resisting type of dust collector can be used for removing the dust in connection with power plants before the gas reaches the heat economy devices, thus preventing collection of dust on such apparatus, and thus improving their regular operating efficiency. It is expected that a temperature over 1000 F should offer no difficulty for such installations, but this matter is subject to further study. Fig. 6 is a schematic layout for thermal shock test on a ceramic tube assembly as devised and conducted by The Robinson Clay Products Company of Akron, O., who supplied these tubes.

Efficiency

Careful studies have been made of the efficiencies of the ceramic apparatus as compared to the steel apparatus, and no differences have been indicated, since the dimensional proportions are nearly alike. The only part which offers any change in proportion is the thickness of the walls of the internal $4^1/_2$-in. tube. The exterior ceramic tube has been made slightly larger internally, so that the distance between the outside of the inner tube, and the inside of the outer tube, will be maintained the same as with the steel tube. The increase is so slight, however, that test observations do not indicate any noticeable difference in efficiency due to the larger diameter.

Special attention should be drawn to the fact that in many industrial installations corrosion of steel is a real problem, and the inactive nature of the ceramic material used in connection with these tubes is a considerable advantage.

BOOKS

1—New Commercial Technical Dictionary

Spanish-English English-Spanish

Compiled by Antonio P. Guerrero

Size 6×9 Price $10.00

Because of the wide geographical distances between the Spanish speaking countries (which has given rise to various dialects and pronunciations) and also because of the many industries that have sprung up in these countries in recent years which involve machinery and equipment from the United States, there has arisen a vital need for a standardized terminology for technical and commercial words. Recognizing this need, the author, a Spanish engineer, has compiled this dictionary and has included all the needed modern words referring to mechanics, mechanical engineering, shipbuilding, etc., and also marine and naval terms, fully defined.

The book is made up in three parts: Part I—Spanish-English; Part II—English-Spanish; Part III—Conversion Tables of Weights, Measures and Monetary Units. The author has also included a page of special explanatory notes which fully explain the makeup of the dictionary and the manner in which it can be best consulted.

2—Plane Trigonometry Made Plain

By Albert B. Carson

389 pages $5\frac{1}{2} \times 8\frac{1}{4}$ Price $2.75

This book deals with the fundamentals of plane trigonometry in greater detail than is done in most texts, and the discussions are presented in such a manner—accompanied by an unusually large number of figures and illustrative examples—that the student is enabled to comprehend how and why the principles are employed, and their practical application.

Beginning with definitions and principles of triangles, the subject is developed in eleven chapters to include inverse trigonometric functions and trigonometric equations. Most of the chapters conclude with pertinent questions and answers, a brief summary of the chapter and many practice problems. The remainder of the book is devoted to logarithmic and trigonometric tables and a very complete 5-page index.

3—How to Read Electrical Blueprints

By Gilbert M. Haine and Carl N. Dunlap

318 pages Size $5\frac{1}{2} \times 8\frac{1}{4}$ Price $3.00

Following a brief section on the making of blueprints and the principles involved in laying out a drawing, the reader is introduced to the subject—How to read architectural blueprints; and in the sections that follow—How to read: diagrams for bell and signal wiring; house wiring blueprints; administration building blueprints; automobile wiring diagrams; diagrams of generators and motors; symbols for control diagrams; motor control diagrams; and power station blueprints. Each section is supplemented with an informative list of questions and answers and a set of "quiz" questions designed to test the reader's knowledge of the subject discussed. The book is admirably illustrated with many line cuts and halftones and, where symbols are presented, each symbol is accompanied by a pictorial sketch of the object or equipment indicated. The book also contains a comprehensive 12-page index and a set of nine instructive blueprints in a back cover pocket.

4—Substitutes

By H. Bennett

Price $4.00

This book should be of interest to all branches of industry where shortages are an everyday problem. It describes new products, processes and substitute materials, and alternatives for the numerous raw materials which have become unavailable because of the war. The author is an expert in this field and has not only given of his own wide knowledge of substitutes but has also included the results of the extensive experience of many chemists, engineers and technical workers.

The contents include: substitutes for metals, plastics, textiles, rubber, chemicals, drugs, resins, waxes, paints, oils, fats and many other products. A plan is given which shows how to determine whether a substitute is suitable or not, and whether it will stand up under conditions of marketing and use.

5—The Steam Locomotive

By Ralph P. Johnson

502 pages Size $6 \times 9\frac{1}{4}$ Price $3.50

This book meets the need of a modern work on the theory and practice of the steam locomotive. Factual material from authoritative sources is presented in a convenient and accessible form.

Some of the subjects dealt with in the first few chapters include Fuels, Combustion, Boiler Water, Evaporation and Superheat, and these are followed by others dealing with Tractive Force, Horsepower, Resistance and Tonnage Rating. Subsequent chapters deal with Curves, Valve Gears and Valve Setting, Acceleration, Testing, Dynamometer Cars, High Speed Trains and also Streamlined and Light Weight Trains. A chapter on Motive Power for High Speed Service introduces the diesel engine, and in the next, pertaining to Switching Service, a comparison is made between steam and diesel locomotives. Two chapters deal with the economic aspects of operation and repairs and the final chapter with the economic life of locomotives.

The book contains 71 tables and 83 line-cut drawings and charts. Six drawings of indicator reducing motions are included in a back cover pocket.

6—Essential Mathematics for Skilled Workers

By H. M. Keal and C. J. Leonard

293 pages Size $4\frac{7}{8} \times 8$ Price $2.00

This book is particularly suited to the needs of men of average education who wish to brush up on their mathematical knowledge and know how to use this knowledge in their work. It is a practical book for the industrial worker and gives a brief, clear-cut working knowledge of arithmetic, algebra, geometry, logarithms, numerical trigonometry and the slide rule, with constant reference to their use in various technical fields and trades.

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Power Trains for Use Abroad

A large number of portable self-contained power plants mounted on special railway cars and designated as "power trains," are under construction in this country for use in devastated areas that have been recaptured from the Axis. They can be dispatched into these areas on the heels of the advancing armies and provide electricity within a few hours for war production, military needs and civilian rehabilitation until such time as permanent power plants can be constructed. They are being built under the Lend-Lease Program and have various rated capacities up to five thousand kilowatts.

Ten such trains, comprising two boiler cars, a turbine-generator car, condenser cars and cars for all necessary auxiliary equipment, will each contain two Combustion Engineering boilers supplying steam at 600 psi to a 5000-kw Westinghouse turbine-generator. Because of limited clearances, the boilers are of special low-head, bent-tube design and they will be fired by spreader stokers capable of handling a variety of coals, also lignite, or wood, if necessary. They may also be readily converted for burning oil. Width and weight were also limiting factors in the designs as the trains will have to be capable of passing all U. S. and Russian railroad standard clearances.

The power trains contain everything that goes to make up a complete condensing power plant with minimum makeup water. As the condensers are of the air-cooled type, designed to operate under extremes in atmospheric temperatures and conditions, availability of condensing water supply is not a factor in determining where the trains shall be located.

Coal Regulations Predicated on Stock Piles

Under the program for bituminous coal distribution which became effective on December 1, industrial plants and railroads having coal in storage equivalent to more than 25 days' consumption, and public utilities having more than 40 days' supply on hand must reduce their current orders for coal to 75 per cent or less of their monthly burning requirements.

An exception, because of transportation hazards, is made in the case of consumers who are dependent upon coal from areas affected by the recent dislocation in coal production and who are located in Canada or are supplied by tidewater in New York Harbor and New England. In such cases, they are permitted to maintain an extra 15 days' supply above the 25 and 40 days' limitation.

Excluded from these restrictions is coal for vessels or bunker fuel, for the manufacture of coke, and that used in the manufacture of gas or chemicals or for foundry and metallurgical purposes. Also, consumers who use under 50 tons or a carload each month are exempt from these provisions.

The program aims to meet immediate needs for bituminous coal by compelling the practical utilization of stockpiles that have been built up in the past year or two against emergency needs. It applies to all coal mined in Districts 1 to 13, excluding 5 and 12. That is, it includes bituminous coal produced in Pennsylvania, Ohio, Virginia, West Virginia, Kentucky, Illinois, Alabama, North Carolina, Tennessee, Indiana and Maryland.

Wrought Iron Used As an Electrical Conductor at Bonneville

Up to the present time approximately half a billion dollars worth of silver has been released by the U. S. Treasury, under Congressional permission, to replace copper, aluminum and tin in war industries. A considerable part of this has gone into electrical buses. Under the existing arrangement with the War Production Board this is to be returned to the Government within a period of five years.

However, engineers of the Bonneville Power Administration have discovered that wrought iron can serve as an acceptable substitute for copper and aluminum as electrical conductors on outdoor bus structures. Commenting on such use, J. A. Gerber, assistant engineer at Bonneville, reports as follows:

1. At 115 kv and 230 kv, the buses are found to be well within the carrying capacity of wrought iron pipe, the largest size required being 4-in. I.P.S. standard weight. The current-carrying capacity may be further increased, if necessary, by slotting the pipe along its length to break the ferrous loop, and by coating the pipe with a dull black paint to increase the heat emissivity.
2. Wrought iron has a high modulus of elasticity, permitting long spans, particularly with ice and wind loading, thus saving on insulators, fittings and supports.
3. It has good corrosion-resisting properties. Paint gives it additional protection and is easy to apply.

4. Welding is an easy, quick and economical way of joining the pipe into whatever bus arrangement is desired. All clamp-type fittings are eliminated, since welding produces joints that have high electrical efficiency as well as permanence.

5. It expands less than copper or aluminum, necessitating fewer expansion joints.

6. It costs less than aluminum or copper pipe of same size.

7. Welded buses reduce corona formation.

The wrought-iron buses at Bonneville were finished by first removing the protective asphalt varnish from the pipe and by cleaning it with an abrasive, then by applying a coat of synthetic red lead and two coats of aluminum paint.

Fuel Consumed by Utilities

The Federal Power Commission reports that the coal consumption by electrical utility power plants during October 1943 was 7,621,986 tons which was 342,768 tons over that of September and an increase of 26.3 per cent over that of October 1942. Of the total, 7,320,910 tons represented bituminous coal and 301,076 tons anthracite.

The consumption of fuel oil during the same period amounted to 1,651,869 bbl which was an increase of 6.1 per cent over the September figure, but there was a decrease of 5.4 per cent in the consumption of natural gas.

Electric output in October 1943, totaling over 19 billion kilowatt-hours.

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request

Boiler Baffles

The Engineer Company has published a 20-page bulletin (BW 43) entitled "Streamlined Baffles" which describes the construction and applications of Enco Baffle Walls. The bulletin is profusely illustrated with halftones and line cuts showing a modern treatment of widely varying makes and types of boilers, furnaces and methods of firing. The cross-sectional views are suggestive of the possibilities of design in reconditioning existing boilers and in plans for new plants.

Boiler Feed Pumps

An attractive 14-page bulletin (No. 42-4500), issued by the Byron Jackson Company, describes in brief the special features of this company's line of double-case boiler feed pumps. The bulletin is well illustrated with unit and installation views, and includes two double-spread pages devoted to sectional views of the eight-stage and seven-stage types, respectively. The former covers a capacity range between 100,000 and 400,000 lb per hr, and the latter from 350,000 to 1,000,000 lb per hr. Pressure range of these pumps is from 1000 to 2000 psi.

Calculation of Pipe Wall Thickness

"Simplified Method for Calculation of Pipe Wall Thickness" is the title of a new 16-page publication (Bulletin 43-A) issued by the Midwest Piping & Supply Company, Inc. The method applies for various pressures and temperatures and is based on A.S.T.M. and A.P.I. Specifications and the A.S.A. Code for Pressure Piping. It supersedes a similar bulletin published in 1937, being based on more definite and authentic data as to the effect of high temperatures on the physical properties of the ferrous and alloy piping materials. Tables and comparison charts are classified in three sections, covering Power Piping Systems, Gas and Air Piping Systems and Oil Piping Systems.

Condenser Tube Manual

Bridgeport Brass Company has just published a new 112-page Condenser Tube Manual which provides a compact ready-reference on tubes used in condensers, heat exchangers and evaporators. It deals with the history and development of comparatively new and more corrosion-resisting alloys, as well as improved Admiralty, Muntz and Copper. Methods of tube manufacture are described and much space is given to the results of research and study of corrosion. The Manual contains the latest A.S.T.M. and Federal Specifications on standard alloys, also comprehensive weight tables, steam notes, methods of installing and packing, cutting and removing condenser tubes. It also contains weight tables and data on brass and copper pipe, copper water tubing and navy type copper tubing.

Conveyor Equipment

Robins Conveyors Incorporated has issued a 6-page folder (No. 125) which gives a brief listing of notable installations of its equipment throughout the world. It stresses the part Robins has played as a pioneer in equipment for handling bulk materials and it pictures many of its specialized products.

General Electric's Amplidyne

The amplidyne, a G-E engineering development which harnesses the usually troublesome short circuit and puts it to work, is the subject of an attractive new 36-page bulletin (GEA-4053) recently issued by the General Electric Company. The publication describes comprehensively the engineering details and fundamental functions of the amplidyne, which in principle is an externally driven direct-current generator which uniquely uses a short circuit and a compensating winding. It also lists several of the amplidyne's typical applications, and in many cases cites figures showing the gain in production levels made through the use of the amplidyne. This publication is profusely illustrated and the final section is devoted to a series of interesting diagrams, with explanatory notes, showing how the amplidyne is employed, in conjunction with other equipment, in various applications.

Electronic Control for Resistance Welding

General Electric Company has published an attractive 46-page booklet (GET-1170) entitled "Fundamentals of Electronic Control for Resistance Welding". It comprises six articles by G-E engineers on the circuits and operation of controls for resistance welding, supplemented by a 6-page section showing controls and accessories G-E has available for resistance welding processes. The articles in the booklet are: Electronic Welding Control; Seam and Pulsation Welding Controls; Special Welding Controls; Timers for Welding Control; Energy Storage Welding Controls; and Servicing Resistance Welding Controls, all of which are admirably illustrated.

Identification of Welded Steel Tubing

Formed Steel Tube Institute has issued a folder entitled "Identification of Welded Heat Exchanger and Condenser Tubing" which shows the identification symbols of twelve companies that manufacture welded steel tubing for heat transfer apparatus. These symbols are used to mark each length of tubing specifically manufactured and tested for this application.

Marine Deaerating Heaters

Elliott marine type deaerating feedwater heaters are described in a 4-page bulletin (N-14) issued by the Elliott Company. The operation of the heater is described and illustrated and a description of special construction features is given.

pH Recorders

Leeds & Northrup Company has issued a 16-page illustrated catalog (N-96-1) describing its line of Micromax pH Recorders. The equipment comprises a rugged glass electrode assembly and a Micromax indicating recorder. A continuous sample of water flows through the electrode assembly chamber; a voltage set up between the electrodes is indicated and recorded in pH units by the Micromax instrument which is available in either round-chart or strip-chart models.

Pressure Control

The Askania Regulator Company has published a 16-page bulletin (No. 100) which describes the applications of the Askania regulator equipment to pressure and control problems. Installation photos and diagrams show how the equipment is used. The bulletin features a valve sizing chart and shows how butterfly valve sizes may be determined in a quick and easy manner.

Preventing Welding and Cutting Fires

To instruct users of welding and cutting equipment in reducing potential fire losses, the International Acetylene Association has prepared a convenient, 16-page, pocket-size booklet entitled "Preventing Welding and Cutting Fires." This booklet, written in easy-to-understand style, contains brief, clear discussions of the chief causes of fires and practical, common-sense measures for preventing them.

Steam Plant Equipment

Yarnall-Waring Company has issued a 12-page condensed catalog (G-1306) which describes its line of boiler blow-off valves, water columns and gages, expansion joints, steam traps and strainers, spray nozzles, and liquid level indicators. The subject of Gun-Pakt and Gland-Pakt expansion joints is specially featured in a 16-page bulletin (El-1909) which also includes tables giving prices, weights, and length, flange and base dimensions.

Armacost Elected Vice President of Combustion Engineering

Wilbur H. Armacost has been elected vice president of Combustion Engineering Company, Inc. to succeed the late F. H. Rosencrants in charge of marine activities. He will also continue to supervise the design of industrial superheaters and economizers, as well as forced-circulation boilers, and be responsible for the chemical recovery units and VU-type steam generators.

A graduate in mechanical engineering of Armour Institute of Technology, 1916, he served during World War I as a lieutenant in the Construction Division in France in connection with a large refrigeration plant at Bassens.

In 1920 he became associated with The Superheater Company and in 1931 was promoted to Chief Engineer of its Industrial Department. When that department was later merged with Combustion Engineering, he was designated as Chief Engineer of the Superheater and Economizer Division of the latter company, later also becoming Chief Engineer of its Marine Department as well as in charge of the design of forced-circulation boilers. Concurrently, for several years prior to 1940 he also was Chief Engineer of The Air Preheater Corporation.

In these capacities Mr. Armacost has been identified with the development and application of multiple-loop superheaters for pressures up to 1800 lb per sq in. and steam temperatures up to 950 F for power generation; also steam temperatures of 1400 to 1500 F for process applications; as well as for economizers and air preheaters of the regenerative type.

David M. Schoenfeld has been made Assistant Manager of the Marine Department of Combustion Engineering, in which capacity he will have charge of proposal engineering, development of technical data and special heat-transfer equipment. A graduate of M.I.T., he joined the Research Department of Combustion Engineering in 1925, later spending some time in its Service and Erection Department, then as an assistant to the Chief Engineer, followed by some five years in sales engineering. He was brought into the Marine Department in 1938 as head of proposition engineering.

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